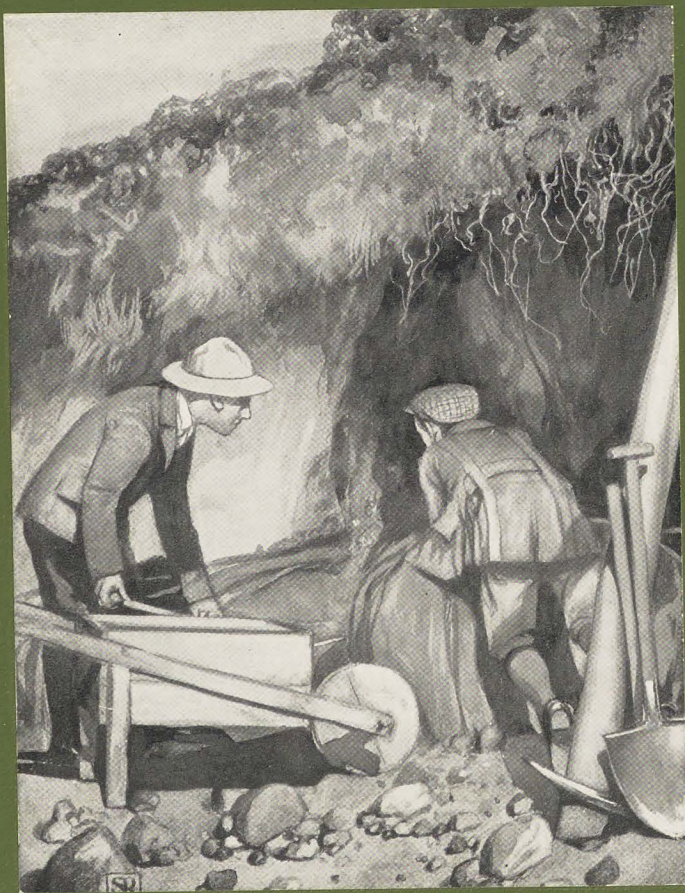
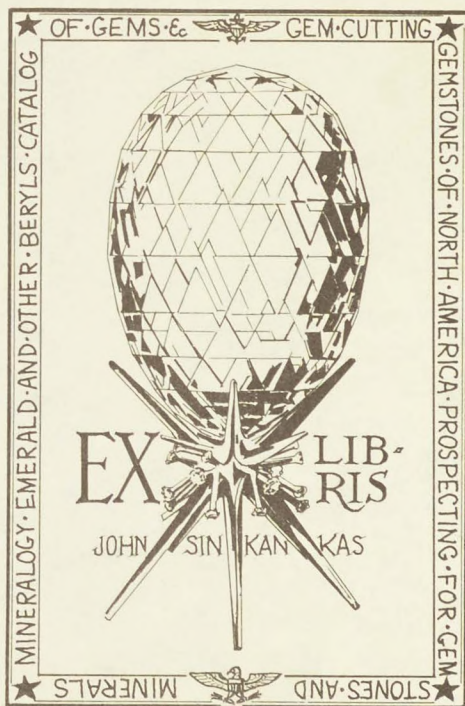


SECRETS OF THE HILLS



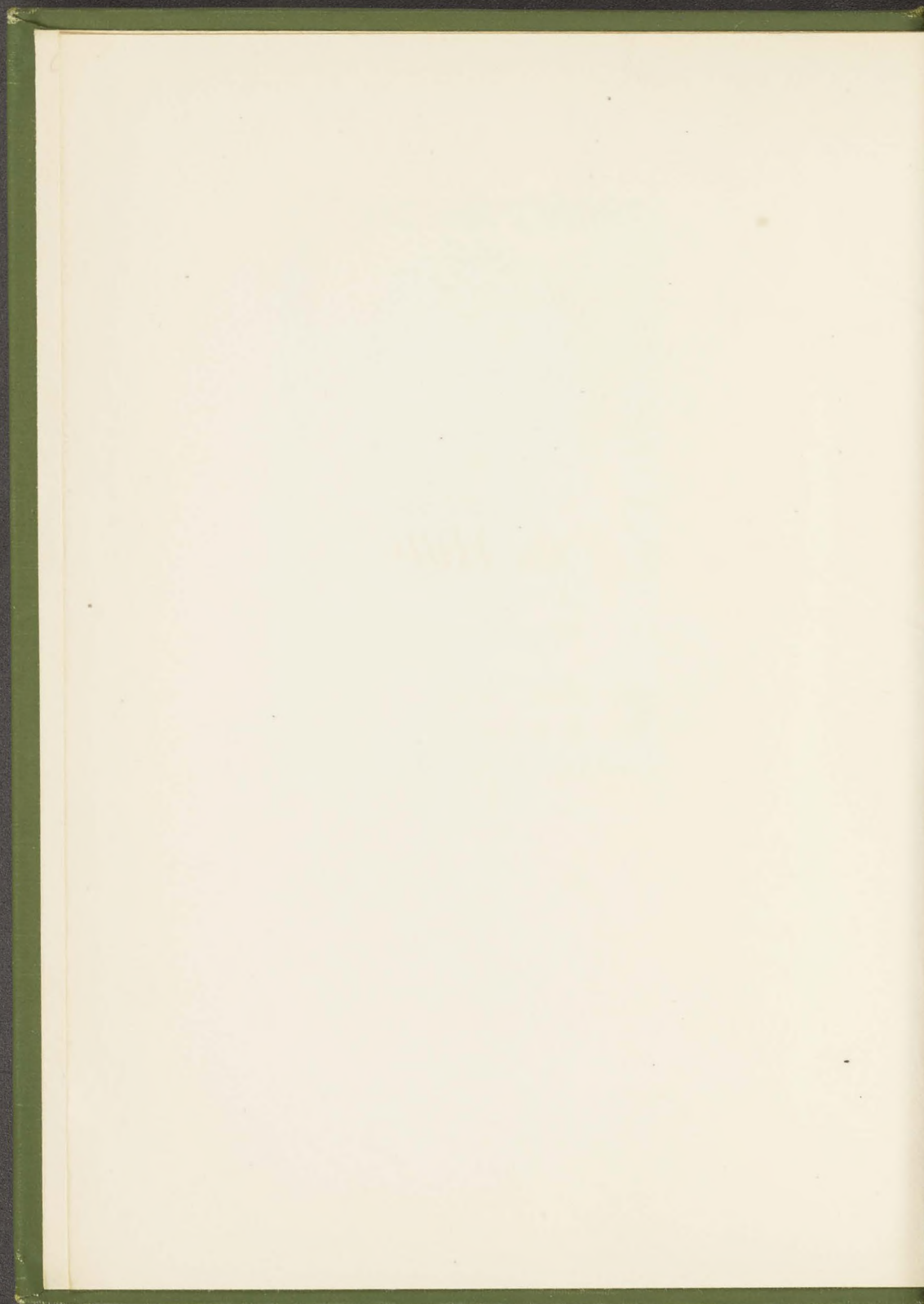
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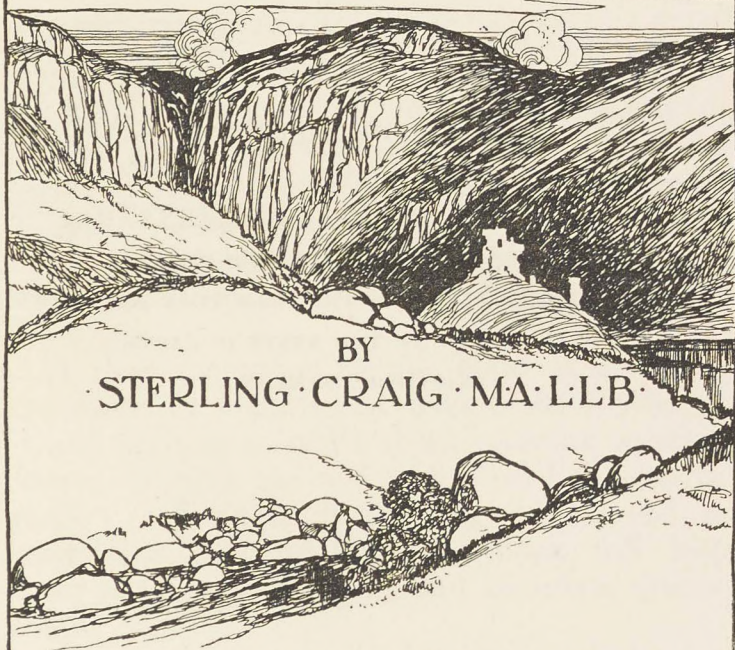
1. Tantallon Castle (*Photo Valentine & Sons, Ltd.*). 2. Dunbar Castle (*Photo Geological Survey*).
 A study of Tantallon Castle would make it possible to reconstruct the more advanced ruins of Dunbar. By similar reasoning geologists could reconstruct from the existing fragments all the layers which were once piled to a height of over 10,000 feet above the present rocks upon which the remains of Dunbar Castle stand, and which have long since been washed into the sea. See Preface and Chapter XVI.

Fr.



SECRETS OF THE HILLS

AND HOW RONALD READ THEM



BY
STERLING CRAIG MALLB.

NEW YORK
THOMAS Y. CROWELL COMPANY
PUBLISHERS

(1911)

TO
MY FELLOW MEMBERS
OF THE
CO-OPERATIVE HOLIDAYS ASSOCIATION
IN MEMORY OF MANY DELIGHTFUL RAMBLES
IN THEIR COMPANY, AND IN THE HOPE THAT SOME ONE
MAY LOOK EVEN AT THE RENTS IN EARTH'S
BEAUTIFUL GARMENT

TURNBULL AND SPEARS, PRINTERS, EDINBURGH.

Preface



THE object of this book is to excite interest in the study of Geology, to introduce a boy to its methods of work, and the principles on which the science is based; and to provide a broad foundation on which he may afterwards build more detailed knowledge of the subject.

A clear conception of the world as a whole, the forces of Nature that have made it what it is, and the way in which these forces are working to-day, is what the author has tried to give the reader; and although he may have failed to reach this ideal, he hopes this book will help some one to use his eyes, and stimulate him to think.

The thread of the story follows a natural order, and begins with the wonder of a city boy at the mountains amongst which he finds himself. He goes in search of gold, and is afterwards taken

Secrets of the Hills

down a lead mine, and told how the metals came to be in the veins; and himself works as a miner in extracting the ore.

He learns how the mountains have been formed.

The boy visits a coal mine, and a description is given of the conditions of life in the carboniferous period, during which the coal measures were laid down.

The work of the sea as the great destroyer and re-maker, is studied during an excursion to Dunbar. The fragmentary remains of the old Castle there, are compared with the much better preserved ruins of Tantallon Castle on the next promontory, and the reader is shown how it is possible, from the existing remains of Dunbar Castle, to reconstruct the original building, by comparing its ruins with the neighbouring Tantallon Castle. By the same kind of reasoning, geologists have been able to determine the existence, at one time, of great layers of rock, stretching across the Firth of Forth, of which the Bass Rock is the only remaining part; the writer explaining how the existence of all the old strata which have disappeared, can be proved by the fragments which are left.

The land-carving work of rivers is examined during a walk up the Devon Valley from Dollar

Preface

to the reservoir at Glen Quey. The results of the excavations necessary for the reservoir are shown to prove the existence of great glaciers in Glendevon during the ice age.

The concluding chapters explain how the Evolution theory gives the chief importance to the study of Geology, and sketch the evolution of life on the earth until it reached its highest development in man.

I wish to express my great indebtedness to Dr B. N. Peach, now retired from the Geological Survey of Scotland, for very kindly reading over the proofs and making many valuable suggestions and corrections; and to specially thank Mr Alexander Drysdale, B.Sc., and Mr R. K. Holmes, of Dollar; Mr W. H. Scott, Leadhills; Mr A. W. Searley, Kingskerwell; and the Directors of the Geological Survey and the British Museum for the use of their photographs; and also Messrs Macconochie and Lunn, of the Scotch Geological Survey, for their willing assistance and encouragement.

S. C.

130 PRINCES STREET,
EDINBURGH, *August 1911.*

Surely there is a vein for the silver, and a place for gold where they fine it.

As for the earth, out of it cometh bread ; and underneath it is turned up as it were by fire.

The stones of it are the place of sapphires, and it hath dust of gold.

There is a path, which no fowl knoweth, and which the vulture's eye hath not seen.

He putteth forth His hand upon the flinty rock,—He overturneth the mountains by the roots.

He cutteth out rivers among the rocks, and His eye seeth every precious thing.—Job, chap. xxviii.

*Trees, clouds, and rivers are enjoyable even by the careless ; but the stone under his foot, has for carelessness nothing in it but stumbling : no pleasure is languidly to be had out of it, nor food, nor good of any kind ; nothing but symbolism of the hard heart and the un-fatherly gift. And yet, do but give it some reverence and watchfulness, and there is bread of thought in it, more than in any other lowly feature of all the landscape.—Ruskin, *Modern Painters*, IV. Pt. V. ch. 18. 6.*

*The more I think of it, I find this conclusion more impressed upon me—that the greatest thing a human soul ever does in this world, is to see something, and to tell what it saw in a plain way. Hundreds of people can talk for one who can think, but thousands can think for one who can see. To see clearly is poetry, prophecy, and religion,—all in one.—*Modern Painters*, III. Pt. IV. ch. 16, S. 28.*

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Chapter the First

Ronald's Journey to Scotland



RONALD was disgusted with everything, and feeling very much ill-used. All the other boys had gone home for the holidays, and he was left stranded in the big empty

boarding-school.

For weeks and weeks he had been longing for the end of the term, and counting the days that stood between him and freedom. Now his sisters had taken measles and his father had written to say he could not come home, but must stay at school until other arrangements were made for him.

It was just like girls to treat him that way. "Fancy! taking measles the day before the holidays. Of course a fellow couldn't help having sisters, and sisters couldn't help getting ill sometimes, but why didn't they get the measles a week sooner? Then he could have gone home with

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Percy Brown, and learned to ride the pony that he talked so much about.

In fact, there were quite half a dozen places he might have gone to, if he had only known about it before all his chums went down; but if there is a silly thing to be done anywhere, some girl is sure to do it!

What a hurry he had been in to open his father's letter yesterday morning, to see how much money he had sent him in addition to his railway fare, and how sick he had felt when he discovered that he was to get no holiday at all.

Next morning (Friday) the old housekeeper was knocking at his bedroom door. "Get up, Mr Ronald, there's a letter for you marked 'urgent.'"

It was from his father, saying that his old college friend, Dr Thomson of Leadhills, had invited him to spend a week there, and that he had telegraphed asking the doctor to take Ronald instead, and the reply had come back, "Delighted to have your boy, send him at once."

Ronald had never been in Scotland, but he had seen pictures of Scotsmen dressed in very strange clothes, and had read several of Sir Walter Scott's novels, so he felt certain that this time he was in for the very best holiday he had ever had. The janitor helped him to pack his bag, and saw him safely into the Scotch Express.

Ronald's Journey

It was a glorious summer day, and Ronald, as the country sped by him, watched the flat fields and slow flowing rivers, the cattle and farm houses, and wondered whether there were any fields in Scotland, or if the whole country were just mountains and rocks and caves.

The train flew through the smoky Potteries, then up through Cheshire and Lancashire. The sight of the sea at Morecambe Bay told him that they were nearing the Cumberland Hills; soon they were in their midst, and he wondered how much higher the Scottish mountains could be!

Ronald and his luggage were deposited at Abington Station, and after a word or two with the Station-master, the big guard waved his green flag, jumped into his van, and a moment later Ronald saw the steam cloud from the engine finally disappear down the valley.

"Ye'll no hae spoken for a machine to meet ye?" questioned the Station-master. "Weel, the lead carts will be gaun up directly, and I'll get Tam Burns to gie you a lift. They bring the bars of lead frae the smelting works every day and generally tak' coals back wi' them. He will be guid company for ye, and it'll cost you naething. Deed, he'll be in the sheds now, and you should just gang round and speer at him yersel. He's a big, lang-legged man with red whiskers."

Secrets of the Hills

Ronald felt that his adventures were just beginning, as he walked down the slope at the end of the railway platform, and along the rails into the goods shed, past hundreds of bars of lead, each about a yard long and four inches thick, and large heaps of curious stones lying beside them. He soon found Tom Burns, who put his bag into a big cart and said, "The horses 'll be needin' another half hour's rest, but after that, we'll be startin', so you can jist tak' a daunder roun' till they are ready."

Ronald looked at the great green hills that began at his feet and rolled away in the distance right up into the sky, and at the stream rushing over the rounded stones in its bed, and wondered if this were really the river Clyde that he had read about in his geography books. Then he began to feel hungry and the Station-master told him he had better go to the hotel. He went to the village and saw a building with "Hotel" in large letters in front. It looked so big and grand that he walked past it two or three times before he summoned up courage to mount the steps and pull the big door bell.

"Yes, dinner will be ready in twenty minutes. What would you like, sir?" said the big waiter, as he ushered him into the dining-room.

"Roast beef and pudding," said Ronald, wondering how much he was going to be charged

Ronald's Journey

for all this magnificence. He felt quite relieved when he had paid his bill and returned to the station.

"Oh, yes, we are jist about startin'," said Tom Burns. "Gang intae the shed and get a pickle straw and mak' yersel comfortable on the tap o' the coals."

Ronald took a good armful of straw, and the carter arranged it in one corner of the big cart, jumped up into the other corner himself, and spoke to the two powerful Clydesdale horses. They pulled out of the goods-yard and off to the hills. Once past the village, Ronald saw the valley opening up for miles before them, and the road stretching through it like a great white ribbon.

"Ye maun hae a try at the gold if ye're gaun to bide at Leadhills," Tom remarked pleasantly.

"What gold?" asked Ronald.

"Why, the gold in the burn."

"But what is the 'burn,'—Do you mean a furnace?"

"A burn's—jist a burn. There is ane doon there, with water in it."

"Oh, I see; 'burn' is the Scotch for a brook."

"You can ca' it 'brook' if you like."

"I never knew there was gold here," said Ronald, recalling stories that he had read about

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the miners who had sought for gold in California and Australia. It never occurred to him that there could be gold lying under the peaceful green hills that he saw all around him.

"Oh, aye, there's plenty o't, but it's no' easy tae get," the carter went on. "Ye see a' thae wee heaps doon there by the waterside? They have a' been turned ower by somebody lookin' for gold. A' the banks o' the burn doon here, hae been turned ower twa or three times, so there is no muckle use seekin' gold there; but you will find plenty at the Windgates or the Deadburn up aboon Leadhills, if ye ken how to look for't."

"But I have never heard of gold being found in this country," said Ronald in puzzled tones.

"Oh, there is plenty. When our Queen Mary was to be married, there was a great gathering to get gold for her wedding-ring, and I saw it afore it was sent up to London. They say the Romans cam' here to work the gold, and there is a Roman Bridge ower the Clyde doon at Crawford. Ye see that tumble-doon hoose fornent thae three dead trees? That's where Bulmer lived. He came ower from Germany to work gold for King James."¹

¹ Sir Bevis Bulmer, Master of the Mint to Queen Elizabeth, had 300 men working, and obtained over £100,000. The workmen were paid fourpence a day. The lead veins were discovered by a German overseer, his name was Cornelius Hardskins.

Ronald's Journey

"And did he get much?" asked Ronald.

"Aye, plenty. They say that ae day the King had some French nobles bidein' wi' him at Edinburgh, and he askit them to gang huntin' wi' him ower the hills here, promising tae gie them a guid dinner and a dish of the special 'fruit of the country,' sic as they had never seen the like o' afore. They had a great dinner, and then a covered plate was placed afore ilka ane, and the King said: 'This is the fruit of the country, but you must not lift the covers till I lift mine.'

"The Frenchmen had walkit the hills a' day withoot seein' a tree or a garden o' ony kind, so they wondered greatly what the fruits micht be. At a sign from the King, they liftit their covers, and every man fund on his plate ten golden Bonnet pieces. 'These,' said the King, 'are the fruits of the country, and you shall keep them to show what the fruit of this country is like.'"



Bonnet piece of
James V.

"What is that smoke coming out of the top of that hill?" asked Ronald. "I don't see any houses and I don't see any chimney."

"That'll be the Smelt Mills whaur they melt doon the lead ore that comes frae the mine,

Secrets of the Hills

into the bars you saw at the station. They take the lead oot o' the smoke tae. You maun gang and see it some day."

The next thing that Ronald noticed was a pony dragging three little trucks behind it, down by the side of the burn. As he watched it, it suddenly disappeared.

"It has gone in at the level mouth," Tom Brown said.

"The level mouth?" cried Ronald.

"Yes—the seventy-fathom level, a road leading into the mine that runs richt under the hills frae here to Wanlockhead. You can go in there and walk on for three or four miles."

"And will they let me?"

"Oh, aye, if you get the manager the richt way I daresay he will let ye gang doon the mines if you can get somebody to tak' ye."

The sun had just set; the sky was a mass of crimson, the purple heather threw back the light, and the whole world was a blaze of glory as Ronald walked up to the gate of the doctor's house.

Chapter the Second

Minerals ana Fairies



CHORUS of dog-barking announced the arrival of the stranger. "Spot," a white fox terrier, and "Jack," a black retriever, came running towards Ronald.

Before he reached the door, the doctor and Mrs Thomson were there to receive him, and welcomed him right heartily for his father's sake.

"How like you are to your father," said the doctor. "I could have told you were John Pickstone's son anywhere. You have your father's very nose, and that twinkle in your eye, when you smile, takes me back to the first day I met him in the chemistry class at Edinburgh University."

"I'm sure the boy must be starving," broke in Mrs Thomson. "We could have waited dinner for you, Ronald, but we never can tell when the lead carts will arrive, they take so long coming

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up the hill, and there are patients waiting for the doctor every night. Let me give him something to eat, Tom, and afterwards you can tell us all about the pranks you and his father played when you were at College together."

Ronald felt strange at first, but when he found what a big appetite his drive had given him, he was not sorry to be left alone. Finishing at last, he crossed the lobby and found the doctor busy with his books. The doctor looked up with a smile, and asked him whether he had ever seen so many pretty stones before.

There was a beautiful collection of minerals arranged in glass cases round the room. The doctor told Ronald that he might open the lids and take the stones out and look at them through the magnifying glass. This was a new delight to the boy. Whenever he had gone to the museum, the things that interested him most were locked up in big cases, with labels telling visitors that they "must not lean on the glass."

Jack, the doctor's son, a student at Glasgow University, came into the room, and the doctor, introducing them, asked Jack to show Ronald some of the specimens in the lower part of the cases while he had a look at the evening paper.

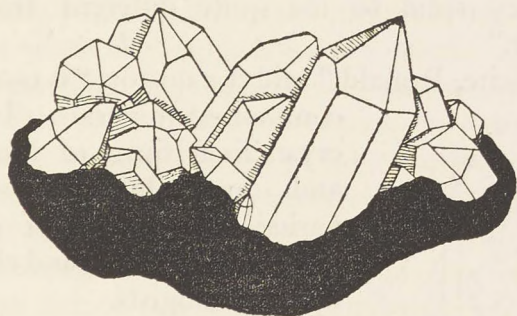
The two lads were soon down on their knees on the floor, exploring the treasures of the big

Minerals and Fairies

cupboards. Jack handed out stone after stone for Ronald to examine.

Ronald was particularly struck with a fine specimen of dog-tooth calcite—a great cluster of brilliant white spires sprinkled over with shining crystals of black zinc ore.

“That one,” said Jack, “weighs over sixty pounds. How would you like to carry it on



Rock Crystal.

your back over a mile along the passages in the mine, and then lug it up seven hundred feet of ladders in one arm, while you pulled yourself up with the other? That's what the man who gave it to father had to do. And these lovely sky-blue crystals too, how would you like to spend hours and hours chipping away the surrounding rock from them—with chisels as fine as darning needles? That was always my job—and then no sooner did

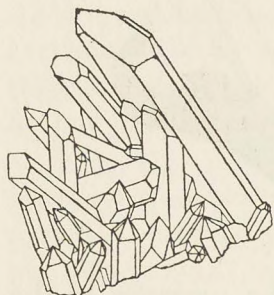
Secrets of the Hills

any person admire it, than father would at once give it him as a present, and I had to chip out another for the collection. There are some of father's specimens in Edinburgh and London, and in almost every museum in the country."

Ronald saw the doctor looking up from his paper.

"Jack calls all these specimens 'calcite,' doctor, but they seem to me quite different from one another."

"Calcite, Ronald," said the doctor, "is one of our commonest minerals. It is the crystallised form of limestone, and seven hundred separate varieties of shapes of crystals have been collected and classified by mineralogists.



Quartz Crystals.

"Nearly every substance has a distinctive shape which it takes whenever it is allowed to do so. This form is called its crystal.

"Crystals are rare, because you can only get crystals of a pure substance, and most of the things in this world are composed of several substances.

"Sugar and salt are the crystals you know best. If you dissolve a quantity of sugar or salt in water, and allow the water to evaporate slowly, you will

Minerals and Fairies

find crystals of sugar or salt in the bottom of the saucer where the solution had been standing.

“When the separate particles of any substance are free to move about amongst one another, and are allowed sufficient time to do so, they arrange themselves in accordance with their own law of crystallisation. If you break a crystal in two, and throw the parts into a solution of the same substance, you will find two complete and perfect crystals when the water has evaporated. Though you grind down crystals to the finest powder you cannot destroy this instinct for arranging themselves. Whenever you threw the powder into water, and caused the solution to evaporate, you would find that the identical crystals with which you started had been reproduced.

“The size of the crystals varies in accordance with the time taken to build them. When a solution is boiled down quickly the crystals are small; when it is allowed to evaporate or cool slowly, large crystals result, but however much the size may vary, the shape is always the same.

“You have watched soldiers being drilled, Ronald, and seen a company ‘form fours,’ and arrange themselves into marching column, or hollow square, according to the order of their officer? The separate particles of a substance do not need a drill sergeant to shout them into their

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places. They received their orders in the beginning of time, and have never forgotten them. They may have been prevented by outside forces from obeying their commander for a hundred thousand years, yet immediately they are free to move, each particle steps into its proper place, and the fore-ordained form of crystal appears complete and beautiful.

“The particles can only move about freely and form into perfect crystals when their substance is at the right heat and at the right pressure, and when there is just enough water present for them to float in. When there is too much water in the solution, each particle keeps floating about on the look-out, as it were, for its partner, but they do not get near enough to recognise each other until the excess of water has been removed by evaporation. There is some water (called the water of crystallisation) in most crystals, even in some of the hardest rocks. If this water is driven out of a crystal by heating it, the particles cannot stand to their places and the crystal falls, all of a heap, into fine dust.

“When a crystal is being dissolved by an acid, or by water, each particle says good-bye to its partner, and sails off from the main body in a definite order. Very beautiful patterns are formed as each face of the crystal is being thus eaten away. The Germans, who were the first to study them,

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have called these patterns 'etching figures.' The particles of every crystal have their own order for parting and reassembling; and crystals can often be identified by their 'etching figures' when other means have failed.

"The law of all the crystals is, that every particle has a partner, and it must go into its proper place, either beside its partner or balancing it on the other side of a line. If it is a hexagonal crystal, for instance, then everything must obey the law of that crystal, which is the law of sixes. Whatever is added at any point, must be repeated six times, or in six pairs. This is the secret of its beauty. All the beautiful patterns of the kaleidoscope are formed by a similar law, out of a few bits of coloured glass reflected in three mirrors. You should take a sheet of squared paper, Ronald, and find how easy it is to form the most beautiful designs, by simply repeating the same line or dot, three, or seven, or five times over, at regular intervals.

"Another law of the crystal is, that every particle must get as near its partner as it possibly can. When two particles come near one another, each tries so hard to get close up to its partner that they squeeze out any foreign particle or other impurity that may happen to be between them. None of the particles of a crystal will have anything to do with a foreigner, so it is squeezed out

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and out by every set of partners as they come together, until it is finally pushed outside the sphere of the crystal altogether.

"The result is a perfect crystal of a pure substance, often surrounded by a crowd of outcasts. If the expelled foreign particle comes across a neighbour, they unite, and begin a crystal of their own substance, and float about looking for more partners. When two crystals have not room to grow, they fight. . . . But you must study the crystals and trace out the history of their loves and hates for yourself.

"You have noticed the beautiful patterns made by frost on window panes. They look like pictures of ferns and palms, and a great many other natural objects. These designs are always symmetrical, and are good examples of water crystals. After a keen frost you will see small pools in the road covered with beautiful ice crystals of all shapes and sizes. When the water cools bodily it sets into a solid mass. We cannot see any crystals in the ice, because, although crystals are formed as soon as the water gets below freezing point, the different crystals are interlocked with one another so closely, like the fingers of your two hands when you clasp them together, and the spaces between them are filled so perfectly by smaller crystals, that the whole mass becomes solid

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and transparent. If you look at a pool of water which is beginning to freeze, or at any crystalline substance in the stage of passing from a liquid into a solid state, you will see the crystals forming like long needles radiating from a centre, or in little bunches or clusters.

“Common sand consists either of small crystals of quartz, or of the remains of larger crystals, which have been broken up. If you examine a few grains of sand under the microscope you will be surprised to see how transparent and beautiful they are.

“Have you ever noticed, Ronald, at the seaside when you have been walking across the damp sand which has just been left by the tide, that the sand round your foot seems to dry up when you put your foot down, and to become very wet immediately you raise your foot again?

“At a meeting of the British Association at a seaside town there was a very lively discussion as to the cause. The first explanation was, that when you put your foot down, you squeezed up some of the sand round your foot to a higher level, and so caused it to dry; and on raising your foot, you left a depression into which the water ran immediately you raised your foot, and so caused the sand to appear wet.

“This explanation was considered quite satisfactory until someone tested the sand with a

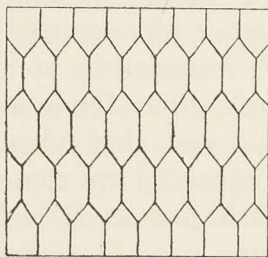
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level to see whether it actually was raised; and was able to prove that the sand was not raised, but remained perfectly flat, both while the foot was on it, and after it was removed.

"Most people held that the sand that was under the foot was wet; and there was a long discussion as to why this was so.

"A school teacher put a piece of window-glass on the sand, and pressed it down with his walking stick, and proved to the learned men, that when he pressed down the sand it dried up, and that no water was squeezed out by the glass. The moment the pressure was taken off, the water rushed up out of the sand.

"How is this mystery to be explained?



Sand Crystals closely packed together.

"If you remember that the sand consists of little crystals of quartz, you will understand the reason. The quartz crystals are six-sided columns with six-sided pyramids on each end. They arrange themselves in rows and they all fit into one another, so as to make a firm compact mass. When, however, you press down some of the crystals, the top layers try to wedge their points into the spaces between the sides of the crystals underneath them.

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These crystals are pushed out of place and tiny spaces are made between them, till, instead of the sand being a solid mass, it is honeycombed with cracks, like a sponge.

“The water from all around runs into these cracks and so leaves the surface dry.

“Immediately the pressure is removed, the crystals arrange themselves again in their natural position, and squeeze out the water from between the cracks, which therefore rises to the surface, and causes the dampness which you see.

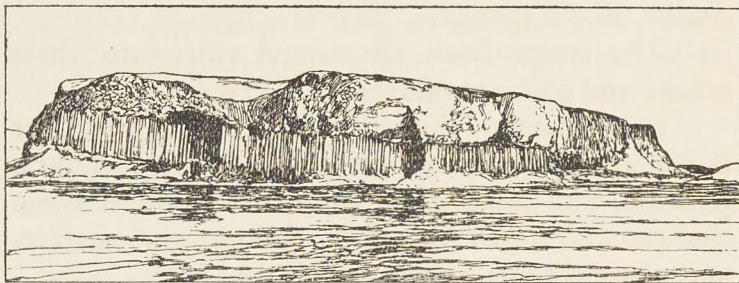
“The sand crystals are packed so closely together that when any one of them is moved, it moves the crystals on each side of it, and they in their turn move the crystals surrounding them, until the motion goes like a wave through the whole sand heap. This is why a heap of sand can stop the fastest cannon-ball.

“The sand crystals don't resist the entrance of the cannon-ball, but one by one they allow themselves to be pushed aside grudgingly, and they in their turn push back the grains behind them, so that the cannon-ball has to move every single grain of sand in the sand heap; and the tiny resistance offered one after the other by these million of scattered grains very soon brings the cannon-ball to a standstill.

“It is the same cause which makes a school play-

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ground covered with gravel such a good thing to fall on, because every pebble you strike moves a little, and therefore lessens the impact of the blow on you.



Staffa, "stave-island."

Fingal's Cave and the *Giants' Causeway* are wonderful examples of columnar structure due to internal contraction while the sheet of lava was cooling. They consist of basalt, a dark grey green rock, which you know better under the name of whinstone. It is used all over the country for making roads. When you have come across a quantity of broken basalt freshly laid down on the road, you probably felt no desire to examine it closely. But if you look at it through a microscope, you will see that it contains a number of beautiful little crystals of other minerals set in a glassy mass. The perpendicular rows of six-sided pillars, which look as if they must have been placed in position by a giant race of long ago, are only found in basalt. It is very rarely that we find the columns as perfect as those of *Fingal's Cave* or the *Giants' Causeway*, because it is very rarely that the mass of melted basalt lava is kept warm long enough to allow the pillars to crystallise out perfectly. You always find the columnar structure in the middle of a lava flow. The rock at the top and at the bottom gets cooled too quickly, because it comes in contact with the cold rocks it is forced in amongst. It is only when the lava flow is thick enough to keep the middle warm for a long time that it settles into the beautiful six-sided pillars. It is easy to see how *Fingal's Cave* has been formed. The basalt columns are separate one from another, like a bundle of firewood after the string has been cut, and when the Atlantic waves got in amongst them, they were broken across and washed out one by one.

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"All these brilliant purple, green, red, and blue crystals, are varieties of quartz, coloured by iron, copper, and other minerals. Here are specimens of many of our best known precious stones, which the chemist and the mineralogist simply class as coloured silica or quartz.

"But how can that be, doctor? for none of these crystals are like each other—they are different in colour and shape."

"They are the same mineral, Ronald, and we can prove this by testing them with acids, and by burning, or melting them with the blow-pipe, or subjecting them to other chemical tests.

"Here is a piece of transparent quartz or 'pebble' from Brazil, used for making lenses for spectacles, because it is much harder than glass, and therefore less likely to get scratched.

"These cairngorms, or Scotch Pebbles, cut and polished to be made into jewellery, are also quartz.

"This case of fluor-spars quite out-rivals the quartz in richness and variety of colour, ranging from the palest amber, green, or sapphire, to the deepest shade of ruby, violet, or indigo.

"The beautiful wavy, many-coloured transparent rings of these Agates have been formed by water laden with dissolved silica, percolating into the steam holes left in lava rocks. They have from ancient times been very highly prized as orna-

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ments. Here is a sketch of some of the simplest forms of calcite crystals. The actual forms in which the calcite is found consists of very intricate combinations of these separate crystals, arranged in symmetrical patterns."

"What are these shining square blocks which look like silver?" asked Ronald.

"These are crystals of galena or sulphide of lead. It is the commonest kind of lead ore and generally breaks into cubes, though you can split the cubes into slices. The crystals of galena have four sides or a combination of four sides. First we have the cube, which has four sides and a top and bottom. Another common form is a crystal made by two four-sided pyramids, joined at their bases, giving a symmetrical eight-sided figure. Sometimes this same double pyramid has all its corners cut off, so that instead of a point at each of the corners, you find a small square.

"Nearly all the richly-coloured minerals in this room consist of different combinations of lead with other substances. You can see at once from their metallic lustre that these shining crystals of galena are lead ore; but you would hardly think that these transparent crystals of cerusite, which look like sheaves of fine glass needles, are actually a form of lead, but if you put a quantity in the fire, they will smelt into pure lead.

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"The diamond, the black-lead in your pencil, the coal we burn in the grate, and the smoke that comes from a tallow candle, are all forms of one mineral—carbon.

"A diamond is simply crystallised carbon. This has been proved by burning diamonds in oxygen. You get exactly the same result by burning a diamond in oxygen, as by burning the same weight of carbon in air. Diamonds have been made artificially."

"But they are not real diamonds?" said Ronald.

"Yes, just as real as diamonds dug up in South Africa, and they are made in the same way.

"Melted iron can dissolve carbon, just as water dissolves sugar. When carbon has been dissolved in iron, and a part of the mixture is suddenly cooled by being thrown into water, the carbon crystallises out in the form of small diamonds. This proves the chemical nature of the diamond, but the stones obtained are too small to be of commercial value.

"The diamonds in South Africa are found deep down in the throats of old volcanoes, the mountain parts of which have all weathered away. The natural diamonds consist of bits of carbon, which have been melted by the intense heat inside the earth and afterwards cooled suddenly. Diamonds have been found inside falling stars, or meteorites,

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as they are called. The body of the meteorite contains carbon and other minerals. It looks to us like a star because it is heated white hot by the friction of our air as it rushes through it towards us. When it strikes the earth it cools, and some of the melted carbon crystallises out in the form of diamonds.

“Copper ores provide us with the most beautifully coloured minerals. This piece glows with the richness of a peacock’s plumage and scintillates in all the hues of the rainbow. It is called ‘iridescent copper,’ from the Greek word, iris, a rainbow. Malachite is another compound of copper, and nothing can surpass the beauty of its alternating bands of dark and pale green.”

Ronald moved from case to case, fascinated by the wonderful variety of form and colour, and the glitter and flash of the lamplight reflected in the thousand faces of sparkling crystals.

“All these beautiful stones,” said the doctor, who had laid down his paper, “have been formed in cracks in the rocks in the very heart of the mountains. Down in absolute darkness, hundreds of feet below the grass and the sunshine, underground water has been trickling for ages moulding slowly these spires and domes, and colouring the crystals.

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"Take the magnifying glass, Ronald, and look into the little hole in this specimen, which is hardly the size of your hand, yet it contains over a dozen different minerals. Gazing into this hole through the glass, you can almost imagine yourself wandering through one of the fairy caves studded with gems, that we read of in the 'Arabian Nights.'

"The brilliance and variety of colour of these metal ores recalls the story of the fairies who caught the end of a rainbow resting on the mountain, and, breaking it into pieces, carried it underground, to show the trolls and gnomes who lived there, what a beautiful thing sunlight was; only to find, that the dwellers in the underworld could display treasures which outrivalled in beauty everything the fairies had brought with them.

"Since you are so fond of these minerals, Ronald, I will give you some to take home with you, but not just now, because I do not wish to encourage laziness, and you can find specimens as good as these for yourself, in the rubbish heaps. If at the end of the time, there are any here that you have not found, I will give you some of mine to make your collection complete."

"Can you really find stones as beautiful as these lying in rubbish heaps?" asked Ronald, eagerly.

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"Yes, but of course you have to look for them. The crystals are so brittle that they are soon knocked off, and the only way to secure good specimens is to break up big stones and take them out for yourself.

"You will find the rubbish heaps all over the hills, wherever the miners have been working the lead veins. Take a hammer after breakfast and go out to hunt for specimens. If you bring them to me, I will tell you whether you have found any good ones."

Mrs Thomson was playing to the other children in the drawing-room, and the sound of little Muriel's sweet voice came through the open door:—

"I'll tell you where the fairies are
Which folk declare have vanished,
Not very near, nor very far,
But neither dead nor banished.
They live in the same green world to-day
As in bygone ages olden,
And you enter in, by the same old way,
Through the ivory gate and golden,
And you enter in, through the same old way,
By the ivory gate and golden."

"Do you believe in fairies, Ronald?" said the doctor, as he rose from his arm-chair, knocked the ashes out of his favourite pipe, and laid it on the mantelpiece.

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"Why? of course not!" said Ronald. "Nobody believes in fairies nowadays."

"Well, I do," said the doctor; "although the scientific people have tried to kill them all, and will only allow us to talk about the forces of nature and chemical and biological processes."

"Modern science has tied long names like millstones round the necks of the fairies, and cast them into the dictionary. I believe, however, that the fairies are making just as beautiful work to-day as they ever did, if we could only train our eyes to see them."

"Come, let us join the others, and have some music before bedtime."

They crossed the lobby, and Ronald was introduced to Bill, a boy of his own age, and to the doctor's two daughters, Lizzie and Muriel.

Next morning, Ronald was awake early. He dressed himself, and stepped out into the garden. Wandering as far as the gate, and feeling that he could not wait till after breakfast, he went across the burn to the mine-heaps, to see if there were really beautiful crystals there. Soon he found himself in a wonderful treasure store, and one after another his pockets were filled with curious stones. When the mine bell rang, Ronald looked at his watch. It was nine o'clock, and he ought to have been home for breakfast at eight. He

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felt rather ashamed of himself as he looked into the dining-room and saw only the doctor left,—the others had all gone to school. The coffee-pot and two covered plates were on the hearth, being kept warm for him.

"I heard you were out at the heaps already, Ronald," said the doctor. "Get your breakfast now, and I'll look at what you have found after I have seen the patients who are waiting in the surgery."

Ronald did not take long to finish his breakfast, and soon the doctor was back again.

"Go out to the pump and wash your stones, and then come and show them to me in the garden."

Ronald felt quite proud of himself, as he brought out a tea-tray full of glistening minerals. He was disappointed when the doctor dismissed the prettiest—shining crystals of pure white—with the remark "That's a quartz,—that's a calcite,—that's lead," and so on.

But when the doctor rising quickly emptied the contents of the tray on to the gravel path, Ronald could not repress a low cry of dismay.

"Keep them if you want to, of course," said the doctor, "but you will easily find very much finer ones than those. If you go into the smoking-room, and examine the outsides of specimens in the cases, you will know what to look for."

Chapter the Third

Down in a Lead Mine



HE doctor had promised to see the manager of the mines and arrange for Ronald to be taken down the following Wednesday; but "Wednesday" seemed far off, and Ronald was anxious to go underground at once.

The very next morning, his opportunity came. As he stood outside a cottage admiring a case of beautiful minerals in the window, a little bald-headed old man, with a hump on his back, but with a very kindly expression on his face, invited him to come inside and look at the minerals for himself.

"Isn't there any way I can get down the mines?" asked Ronald, when the specimens had been restored to their case. "The doctor said I could go with the under manager next Wednesday, but I don't want to wait till then. I saw some boys not much bigger than myself going down

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with the men. Why is it not dangerous for them, if it is for me?"

"Everybody here has his work to do," returned the old man smilingly, "and cannot leave it just to take you down the mine and up again."

"But I have made up my mind to be a proper miner, and I want to learn. Cannot I go as a learner?"

"If you are staying with the doctor, you might get one of the miners to take you down. I will speak to my son and see if he will let you go with him. He will be home again about three o'clock."

Ronald did not wait to finish his pudding that day, but ran off as soon as he could, to his new friend, who took him round to the office to ask permission to go underground.

The manager, an old man, with grey beard and white hair, smiled as he saw Ronald's eagerness. "Well, if Jim Black likes to look after you," he said, "you can go; but once you are there, you must stay for the whole day."

"But mind," he added, "if you are going to be a miner you will have to work, and you must not change your mind as soon as you get your fingers chappit."

"You cannot go down in those clothes and shoes," Jim Black remarked as they left the

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office, "for they would be knocked to bits in no time,—we will see what we can do for you at home."

The idea of the English boy going down the pit was soon the talk of the row, and Ronald found plenty of people willing to help to rig him out. He was determined to be a proper miner, and was soon possessed of some old corduroy trousers, a rough jacket, a cap, and a miner's lamp. A pair of real miner's boots, which he bought from the store to fit himself, completed his outfit for the next day.

The "shift" began working at six in the morning, so Ronald arranged with the cook to waken him early, and make up a proper miner's dinner. He crept downstairs before anyone else was awake, and had some breakfast in the kitchen, while the good-natured cook had many a laugh at his strange clothing. Then, with a flask of tea, and four thick sandwiches wrapped up in newspaper, he sallied forth to be a real miner.

"That cap will never do to go down in," said one of the men. "Here, try this one."

The cap offered to him was so dirty that Ronald almost shuddered as he put it on his head, but as it had a catch sewn on to it for holding the lamp, and his own had none, he accepted it gratefully.

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"The smith has sent your tools with the rest to the 'heading,' and you will find them there when we go down," said Jim Black, briskly.

All the wives, who were preparing their husbands' breakfasts, came to the cottage doors to smile at Ronald, and many a cheery word and good-natured caution he received, as he passed the doors.

"I thought you were going down the mine," he cried a little later, as his companions, instead of continuing the road to the pit head, struck into a path leading up the mountain-side.

"So we are," they answered, "but the level where we are working is on the other side of the hill."

Ronald had often seen the top of a coal mine, and had watched the great pulley wheels whirling round and round. He had heard so much of the deep mines going right down into the earth, that he thought this could not be a proper one, unless he went down into it in a cage. But he found he was mistaken.

"Coal, ironstone, and other 'flat minerals,' as we call them," explained his friend, "are usually spread out in fields, lying like the pages of a book. Once you get down to their level, you have nothing to do but dig them out. Metal veins are different. The vein, instead of lying flat, goes

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right down from the surface, towards the centre of the earth, like an axe head driven through the pages of a book, and cuts all the layers of rock. Of course you could go from the place we are working, up to the pit head, but it is a very bad road, and it is easier for us to walk over the hills till we reach the level mouth, and then get down to our work."

Soon they came to a hole in the hill-side, with rough door-posts in front of it, giving entrance to a dark passage. The miners began to take off their coats and vests, and hang them up on nails driven into the wooden supports of the roof. Ronald promptly removed his jacket also, as he was determined to be a proper miner.



Tunnel Mouth.

"We have to take off our coats," Jim told him, "because it is so much warmer down in the mine, and we shall need them again when we go out to the cold air; but you had better keep yours on."

"There is a great fire always burning in the inside of the earth. The deeper we go down, the

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nearer we get to this fire and the hotter the mine becomes. Heat and water and bad air are what the miner always has to fight against."

"But I am going to work, too," said Ronald.

"I ken that fine," said Jim; "but you promised the manager to do everything I told you, and so you will just keep on your coat."

The other men were lighting the lamps on their heads; Ronald lit his too, and felt it swinging against his brow as he walked along the dark passage.

Water was now dripping from all parts of the roof, and a little stream flowed out along the middle of the rocky tunnel.

About two hundred yards on, the party came to a stop. Pulling up a trap door, Jim explained to Ronald that they had to go down ladders for about five hundred feet. One man would go in front, and another behind him, so that he would always see their lamps.

Ronald stood at the top of the hole as one after another climbed down the ladder, the lights on their caps gradually growing dimmer and dimmer, until they disappeared altogether.

"Now, if you are frightened," Jim whispered, "You can easily find your way back to daylight. And mind, you will be lying in your bed tomorrow after going down all these steps."

"I'm not the least frightened," Ronald replied,

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as he looked back at the dim glimmer of the daylight away at the end of the long black tunnel they had walked into.

"Come on!" cried a voice out of the hole, and Ronald took hold of the top rung of the ladder, and began to go down.

How cold and slimy the wet ladder felt! With his nose just above the level of the ground Ronald glanced back at the faint trickle of daylight stealing along the water in the bottom of the passage, and wondered if he should ever see the outside world again.

"Are you right now?" asked Jim Black, as he pulled down the trap door and closed the shaft.

Ronald suddenly found himself sitting on a cross beam.

"That's a 'landing' put there in case anyone falls," said Jim, noticing that he had stopped. "Squeeze yourself past between it and the ladder."

Down, down they went, one ladder after another. Ronald had left off counting the steps when he had reached three hundred and fifty-nine. His companions came to a stop, and he found he was standing in another long narrow passage. As he listened he heard the sound of running water.

"Where does it come from?" he asked.

"That is the water from the 'fifty fathom level.' We'll be coming to it presently."

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Ronald followed his companion along the passage, always taking care to keep his head well down, for the moment he stood up, his lamp was promptly knocked out by one of the cross beams which supported the roof.

The sound of rushing water grew louder and louder, and Ronald stopped in amazement when he came to a great underground river. His friends took the lamps out of their caps and held them down, to allow the boy to see the planks along which they were to walk.

"We have to go along these planks for about a quarter of a mile," said one. "Take care of your feet, because they are very slippery. Tom will hold his light behind him, to show you where to put your feet, and I will catch you if you tumble."

It was the strangest walk Ronald had in all his life. He listened to the sound of the running water beneath them, and the "plung," "splish," "splash" of the big drops that fell into it from the roof. The rest of the party had reached their working places and started work long before this, for Ronald's friends had taken more time in coming, because he could not climb down the ladders as quickly as the miners who did it every day.

Now that his eyes had become accustomed to the darkness, he could make out the walls of rock on each side of the passage, and see the roof above

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him. The whole of the rock was covered with grey mud, and queer things were hanging from the damp walls. Feathery white and brown fungi were growing out of the pit props which supported the roof. It was certainly the strangest place. Ronald heard the footsteps of the three of them echoing and re-echoing in the distance, behind and before, but it took him all his time to keep his eyes on the plank, and watch that he did not slip off into the rushing water beneath.

"Now we have to go up ladders for a hundred feet or so, and then along another passage and down to our working place," said Jim. "Do you know where you are?"

If Ronald had been told that he was five miles away, he would have quite believed it.

"You are under the Curling Pond by the march dyke," laughed Jim, "and when we get to the end of this level, you will be just under the doctor's house."

Ronald pictured the doctor and his family, all lying fast asleep in their beds about five hundred feet above him, and thought how strange it was.

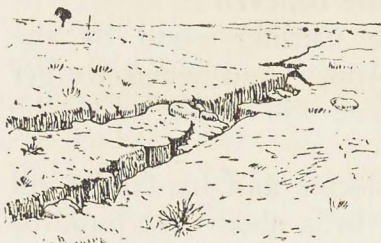
At last they reached the working place, and Ronald was given two hammers and a bundle of long chisels, wedged tight in an iron ring. He was very keen to begin work at once, but was told to sit down and watch the others for a little

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until he got used to the darkness. After he had sat for a minute or two he felt his back getting cold, and putting up his hand, found that his jacket was soaked through. A little stream of water had been dripping from the roof on to his shoulder all the time.

"This is what we call the vein," explained Jim. "Lead, gold, copper, silver, and zinc, and all the other metals except iron, are generally found in a vein of quartz or other rock which has crystallised out of water. The vein very seldom goes straight up and down, but is slightly slanted. The rock which overhangs the vein is called the 'hanger,' and the rock below, the 'ledger,' wall, or floor.

"This metal-bearing vein has been formed by the filling up of a deep crack in the earth's crust. Sometimes the space between the 'hanger' and the 'floor' widens out to twenty, or thirty, or even forty feet, and sometimes these walls come so close to-



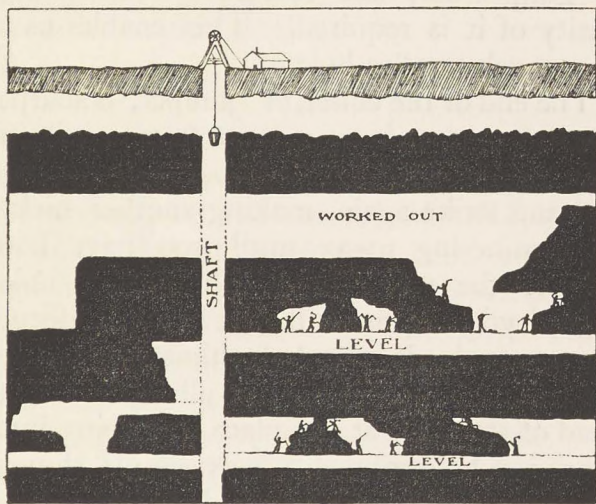
Earthquake Crack, Arizona.

gether that you could not squeeze yourself through sideways, and then a passage has to be blasted out of them."

The working place was a long, low, narrow

Down in a Lead Mine

tunnel, exactly like those they had been walking through, only they had come to the "face" of solid rock in the end of it. Their day's work was to cut the passage four feet further into this solid rock.



Section of lead mine along the vein. This is what the mine would look like, if the hill were split through along the vein and one side of the hill were lifted away.

"The quartz vein rock is very hard, and in the old days we used to work it out by one man holding, and slowly turning, a heavy 'jumper'—a long chisel over an inch in diameter—while another struck the end of it with a hammer, until they gradually ground away a hole in the rock.

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When the hole was bored, it was filled with gunpowder and exploded, breaking up the rocks so that they could be easily removed. Now we use dynamite, which is very much more powerful than gunpowder, and therefore a much smaller quantity of it is required. This enables us to do with a much smaller hole.

"The end of the chisel, or 'jumper,' is sharpened, and when you strike it with a hammer, it makes a nick in the stone; then you turn the jumper round and strike again, making another nick, and keep hammering away until you have bored a hole into the rock. Now, I'll start a hole for you, and you can finish it. It is very difficult for a learner to begin the hole himself, because the chisel is apt to jump about all over the rock, instead of stopping at one place and going into it."

Boring a hole seemed a very simple thing, and Ronald took off his jacket, folded it beneath him for a seat, and started hammering at his jumper, which was placed in a hole in the rock. Hammer, hammer, hammer; and still the jumper never seemed to get any further in.

"Put more strength into it, Ronald," said Jim, "and take care of your fingers. Remember the jumper does not go into the rock by itself."

Chapter the Fourth

Ronald as Lead-Miner



SEVERAL times Ronald missed the jumper and hit his hand, but he was determined to be a miner, and he noticed that every time he stopped, the men were smiling at him. So he kept on, although it must be confessed that he took his jumper out to measure the depth of the hole very much oftener than was necessary. Still the hole was always getting a little deeper, and he felt quite proud of himself when he showed Jim Black that a "jumper" a foot long, went right down into it.

At the end of three hours, Jim Black and his chum had each bored two holes about three feet long, and by this time, Ronald had cut his hole about a foot and a half deep.

While the hole was being bored, the miners put in small quantities of water to keep the jumper from getting heated and sticking. This water is

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forced up out of the hole again by the jumper, and brings with it the powdered rock made in boring the hole. The hole had to be cleared out before the explosive was put in.

A mop was made by fixing some threads of cotton waste into the split end of a thin iron rod, and the hole was dried out with this mop; then Jim Black brought a quantity of dynamite cartridges, that seemed to Ronald just like macaroni cut into pieces about three inches long. It was not so stiff as macaroni, but more like jelly. These cartridges were put into the hole one after the other, the number being regulated in accordance with the amount of work which the dynamite had to do. Then a length of gunpowder fuse was attached to a detonator cap. The cap was pressed into the middle of the last dynamite cartridge, and pressed into the hole in the rock, leaving about two feet of the fuse hanging out. The rest of the hole was then filled up with mud and rammed tight. When all the holes had been charged, Jim Black told them to gather up their tools and make for a safe place before the shots were fired.

As Ronald was very anxious to light the fuse in the hole he had bored, he was allowed to do so. He saw Jim Black take his lamp and set fire to each of the four fuses, which looked like pieces of window-blind cord hanging out of the rock.

Ronald as Lead-Miner

Then they had to get out of danger as quickly as possible. Looking back Ronald watched the gunpowder sparking away in the darkness, and felt not a little afraid of the mighty power he knew he had invoked when he lighted the fuse. He wondered how big a piece of rock his charge of dynamite would blow away.

"Now we're round the corner, we'll wait until the shots have gone off," said Jim.

As they listened they heard echoes of other shots being fired in different parts of the workings, like distant thunder rumbling through the mine above and beneath them.

"Our shots should be ready now. Listen!" Bang, came the noise, and Jim counted "one." Bang again, "that's two." A little bang came, "That will be your hole, Ronald," "three." Then "four," but the pause seemed long ere the fifth shot went off.

"We must allow some time for the smoke of the dynamite to clear away, and the air to be purified for us to breathe in," said Jim, "so we will have our 'piece' now, and when we have finished our lunch, we will go back and clear away the broken rock.

"All the miners in this part of the mine eat their meal at the cross roads. We take our 'pieces' together, so as to be sure we are all here,

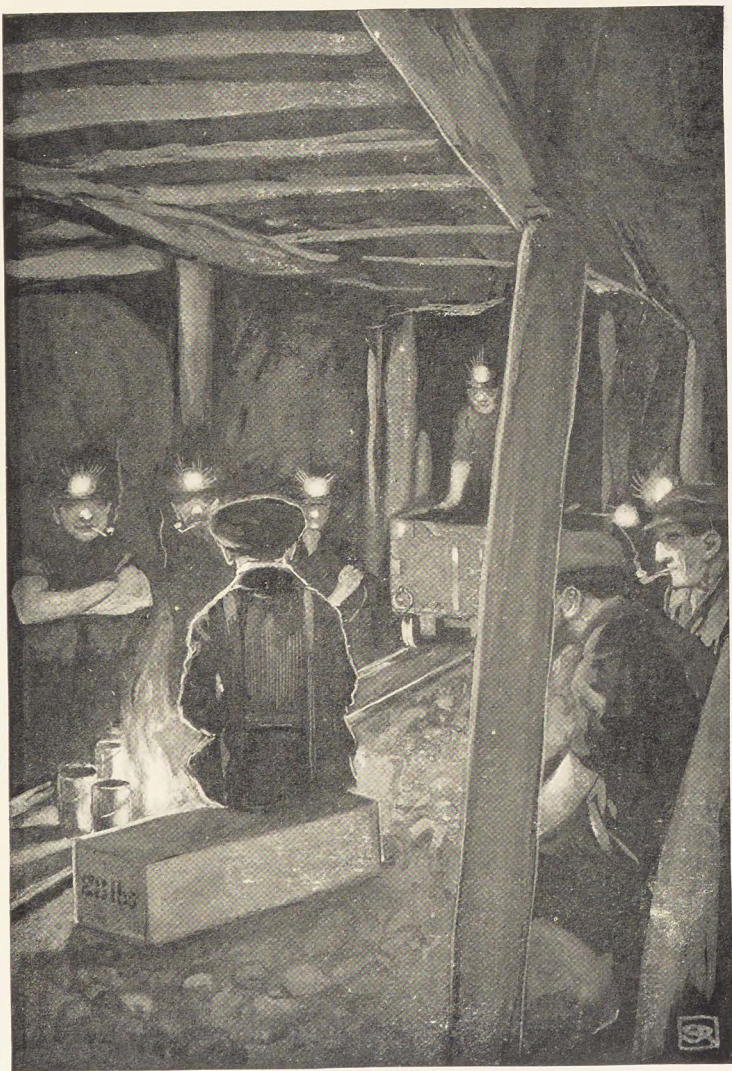
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and if any man does not turn up, we send someone to look for him at his working place, because it is always possible that he may have been hurt, or that some great stone might have fallen on top of him. There have been many cases of miners who have been crushed, or slowly bled to death, all alone in the darkness."

Ronald and Jim climbed the ladder and went along another long passage, and as they walked, they could hear the sound of men talking, and saw the glimmer of lights in the distance.

Ronald will never forget the weird picture the miners made as they sat eating their dinners in the darkness. A room had been cut in the rock like a great cave, and round its sides miners were sitting on their heels with their backs leaning against the rock. Their clothes were all covered with mud, exactly the same colour as the mud that covered the rocks round about them, and he had to look carefully in the half darkness to make sure whether the crouching figures were men or stones. Each man had a little miners' lamp in his cap, which lit up his face, and at the same time threw strange shadows round the hollows about his nose, and mouth, and eyes.

They reminded Ronald of the pictures of gnomes and dwarfs of the fairy tales, and made him almost believe in the reality of the trolls and



After Dinner in the Lead Mine
Stephen Reid



Ronald as Lead-Miner

goblins who were supposed to inhabit the underworld.

He received quite a warm welcome, every one of the men insisted on shaking hands with him, and enquired how he liked being a miner?

Jim Black made a little fire by soaking bits of the lamp wick in oil and setting it on the floor, and round this fire the men put their tea cans to warm.

Ronald could not get used to the miners' way of sitting on their heels, and wanted a raised seat. He saw a clean wooden box on a shelf in the wall,—“Yes! just take that,” said one of the men with a smile, and Ronald took it down and placing it near the fire sat and warmed his hands over the flame.

After he had finished his tea and sandwiches, the miners asked him if he knew what he had been sitting on. “No,” he replied; they told him to open the box, and there, to his horror, he found that it was full of dynamite cartridges, and contained 28 lbs. of dynamite.

Ronald was shocked with fright, at the risk he had been running, but Jim Black assured him that there was really no danger, as dynamite would burn quite slowly if put in the fire. It would not explode without a detonator, or the shock of a sudden blow, or of another explosion near it. Otherwise it would burn away in the air,

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and make no explosion at all. The other men took fresh supplies of dynamite, and Ronald filled both his waistcoat pockets, just to show he wasn't afraid of it, but he didn't like the feel of it bulging into his sides, all the same.

"I see the lead ore is here in the rock right enough," said Ronald, "but where did it come from, and how did it get here?"

"The lead vein," said Jim Black, "has been formed in a great crack in the rocks. These cracks go down from the surface of the earth, right through all the rocks, till I suppose you would come to a place where, instead of being solid, the materials which make up the rocks are melted by the intense heat inside the earth.

"The quartz vein that we are now working at has been formed by water running up and down this crack. Whenever the water finds a hole or crevice in the rock, it begins to fill it up. The water which trickles down through the rocks, dissolves a small part of the rock that it has run over; especially when the rocks contain lime, or similar substances. When the water gets into a hole and stays there, it is slowly evaporated, and the lime is left in the hole and gradually fills it up. You would notice curious things hanging from the roof and the sides of the passages as we came along, like the stems of clay tobacco pipes. They

Ronald as Lead-Miner

are called *stalactites*. If you observe them carefully you will see there is always a drop of water at the end of each stem, and they are hollow in



Stalactites filling up a Gallery.

the middle. They look like icicles, but instead of being formed of frozen water, they are formed of lime-stone which has separated itself from the water and hardened, particle by particle, as the water left it when it dripped to the floor beneath.

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"You will often see similar stalactites hanging from the roofs of stone railway bridges. There, though, they have been formed by water which has dissolved the lime out of the mortar with which the bridge has been built. These are only a few inches long, but in some caves in limestone districts there are stalactites 20 feet long and 10 feet thick, and in other caves the stalactites have grown so big that they have filled up the cave and made it almost solid rock again.

"We do not know yet where the lead and the other metals came from. Lead, tin, silver, copper, gold, nickel, and antimony are generally found near one another, and are supposed to have crystallised out of water. You have often watched your mother making jam, and you know that sugar dissolves in hot water very much more quickly than in cold. When syrup is left uncovered, you will notice that the water evaporates, and you can see the grains of sugar left on the plate or basin, or on top of a pot of jam.

"In the same way if a solution containing lead or any other metal becomes cooler, the water cannot hold as much of the metal dissolved in it as it did when it was warm, so the metal crystallises out and sticks to the side of the crack in which the water is flowing, or standing.

"Now, when the metals were being put into this

Ronald as Lead-Miner

vein, water containing lime and lead, and other minerals dissolved in it, was lying somewhere in the middle of the earth, and in consequence of the great heat there, was forced up into this crack. When it came nearer the surface it cooled, and as it could not retain the lead and quartz in solution any longer, they crystallised out of it, and were deposited in this vein we are blasting them out of to-day.

“You see the two rocks that we are always working between,—the ‘hanger,’ and the ‘ledger’ rock!

“These are part of the old rocks forming the crust of the earth, and we know that there is no lead in them. The lead veins fill up the cracks in the original rocks, and there seems to be no law as to where we are to find the lead.



Rich part of Vein or “Lode.”

Some veins have been traced through the hills for miles and miles, and then suddenly the old vein will stop altogether, and a new vein will appear, or the one vein will divide into three or four small cracks. You will see the same thing, on a small scale, if you look at the sun-cracks in the dried-up mud at the bottom of a pond.

“We find the metal bearing veins where the top

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layers of the earth's crust have been cracked by great masses of molten rock which have forced their way up from beneath, and have broken and pushed up the overlying rocks to make room for themselves. The metals are derived from these intrusive igneous rocks.

"The whole of the space between the 'hanger' and the 'ledger' walls is filled solid with the vein stuff. As there is more or less lead ore scattered through all the vein, we take the whole of it out.

"First we bore a set of slanting holes into the rock converging towards a centre like the ribs of an umbrella. Then we charge them with dynamite and explode them all at once, and so blow out the piece of rock they are surrounding. After we have made this big hole in the face of the rock, we "square it out" by boring holes along the top, bottom, and sides, and blowing the surrounding rock into the hole."

After the men had had a smoke and a chat, they went off again by ones and twos to their different working places, and Ronald and Jim Black returned to their level to examine the results of their blasting.

Ronald saw some of the lead ore shining quite brightly in the rock, and to his delight found a little cave of white calcite crystals. After the stones and ore had been cleared away, the miners

Ronald as Lead-Miner

started boring holes again for the next shots, but Ronald's hands were too sore, so he sat on their coats and watched them. After firing the shots again, the day's work was finished, and Ronald and his friends began their journey home. Up the ladders and along passages, and on planks over the under-ground river, and up ladders again, until at last they came to the welcome daylight.

"It's easily seen you haven't been working much since piece time," said one of the men to Ronald, as they were putting on their coats, just before stepping out of the hill-side.

"How's that?" said Ronald.

"Because your face is far too clean for a miner. When you are hammering the jumper into the hole in the rock, the water in the hole squirts out, and strikes your face. Everybody will know you haven't been working if you go home with a face as clean as that."

Ronald immediately rubbed his fingers on the wet mud on the side of the rocks, and wiped them on his face.

"I'll show you a better trick than that," said Jim Black, as he held the flame of his miner's lamp underneath a projecting stone until a little soot had collected, and then decorated Ronald's face with a few effective black lines.

"Stop it, Jim," said the other miners, "you're

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making a fool of the thing!" and Jim, seeing he had done a little too much, rubbed some of the soot off again. "Now put a little more dirt on your hands and you'll look like a proper miner."

As they passed the minister's garden, Ronald saw the three girls he had been playing with the night before. He looked up and smiled, but they took no notice of him. He felt rather hurt, but then he remembered the sight he was, and knew that they couldn't be expected to recognise him.

A little further down they passed a man with two baskets, selling plums. A bright idea occurred to Ronald, so he turned back and offered to carry one of the baskets for him up to the minister's house. The three girls came to buy the plums, and Ronald began, in the best Scotch he could manage: "You would be hearing about the English boy that went down the mines to learn to be a miner."

"Yes," said the girls, "he was here to tea last night. But why are you looking so serious? Has anything happened?"

"Aye!" said Ronald, very gravely; "it was this way. They were all sitting down to eat their piece, but the English boy didn't seem to like sitting on a wet stone with the rest of them. He saw a nice clean wooden box on a shelf in

Ronald as Lead-Miner

the wall. It was rather heavy, but he took it down and brought it close to the fire, and sat down on it to eat his dinner. Well, it was crammed full of dynamite, and he never knew anything about it till he poked up the fire and—and—"

"Oh—Oh—Oh," said the girls.

"Well," said Ronald, very solemnly, "he'll never come up now!"

"Oh, you don't mean it!" cried the girls, all at once. "He's not dead? is he dead? But I knew something would happen."

Ronald could keep it up no longer but grinned all over. "He's come up already. Don't you know me?"

"Oh, you wicked boy, to frighten us that way," said Jessie. "But you do look like a real miner. Just come in and see if mother can find out who you are."

Chapter the Fifth

The Rising and Sinking of the Earth's Crust

*There rolls the deep where grew the tree.
Oh! Earth! what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea.*

*The hills are shadows, and they flow
From form to form and nothing stands;
They melt like mists, the solid lands,
Like clouds they shape themselves and go.*

TENNYSON.



YOU told us last night, doctor, that some people believed that gold had originally come from sea water; and that the lead we find in the veins in the rocks has been deposited by water, which had dissolved it out of the surrounding rocks as it filtered through them, but to-day you told Willie Grant that you could not believe that he had really found a reef of gold quartz in the side of the mountain, because the rocks which contained the grains of gold which we find in the

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burns, must have formed part of the tops of mountains at least two thousand feet higher than the hills we see here to-day.

"I cannot understand how there can ever have been mountains here in Leadhills two thousand feet higher than these are, and it is quite impossible that the gold can have been deposited out of sea water, because that would mean that the sea once rose high enough to cover up mountains twice as high as these; and there is not enough water in the whole world to do that. How can you explain it?"

"You have given me a very difficult question to answer," said the doctor. "We are apt to think that the earth has been the same for ever and ever, and people say that a thing is 'as old as the hills,' because they think of the hills as the oldest and most unchanging things in the world; and so of course they are. The sea is the only thing in the world that never changes."

"But, father," interrupted Bill, "if the world is round, and the sea can go up to the top of the mountains, how is it that the sea does not run down off the earth altogether?"

"One at a time, Bill, I must try to answer Ronald. He says the sea is not deep enough to come up to the top of the mountains, because, as Jack tells us, even in its deepest place, it is only

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about five miles deep, and there is not enough water in the world to make the sea deeper by another five miles, which it must be if it is to rise to the top of the highest mountain. It is not, however, the sea that rises, but the mountains that sink down."

"How can the mountains sink?" asked Lizzie. "The earth is solid, and the mountains are lying on the earth already. How can they sink any further?"

The doctor caught sight of baby's ball, which had been laid on the sideboard after the dog had been playing with it. When Ronald rescued it, he found it was crushed in and would not bounce; but Jack said that if they left it alone for a while it would come all right again.

"Bring me that ball, Ronald," said the doctor, "and I will try and explain how it is that the mountains can sink down under the sea, and then rise up once more. What do you think is wrong with this ball?"

"I think that 'Spot' must have made a hole in it somewhere with his teeth, although it is too small for us to see," Jack replied.

"Well, children," said the doctor, "before this happened to the ball, it felt quite hard and solid and I could not press it in. If it fell on the floor it bounced up again. If we let it drop now

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it does not bounce, and when I pick it up, you see two hollows where my fingers have been.

"If I press the skin of the ball in on one side, it comes out all right on the other; but there is always a hollow left somewhere. The reason for this is that some of the air, which formerly filled it completely, has escaped, and so the ball is not now quite full. In other words, the skin of the ball has become just a little too big for the smaller quantity of air inside the ball. In some ways our earth is just like baby's ball. It feels quite hard and solid, and the deepest mine that has ever been dug has not got beyond hard rocks. But in reality, the inside of the earth is no more solid than the inside of this ball. The ball is filled with a liquid which we call air, and the earth is filled with a liquid which we know to be composed of melted rocks. The solid crust of the earth as compared with the size of the earth itself, is just as thin as the skin of this rubber ball."

"Oh, doctor, how can that be?" said Ronald. "We have mountains over five miles high and the sea is five miles deep. And there are rocks for miles and miles below the bottom of the sea."

"How high is this ball, Ronald?" "About six inches, doctor." "How thick is its skin?" "About half a quarter of an inch!"

"That is an eighth of an inch, Ronald. But,

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the skin is, let us say, one-tenth of an inch thick. How many times is the ball thicker than its skin?" "Sixty times, doctor."

"Now, how thick is the earth?"

"Eight thousand miles."

"What is the sixtieth part of 8000 miles?"

Ronald worked it out at 133 miles! "So that if the earth's skin were as thick in proportion as this ball's, it would be 133 miles thick. But the heat of the earth increases so rapidly as we go down into it, that at a depth of 20 miles it must be hot enough to melt everything inside it. It follows, therefore, that the earth's crust cannot be thicker than 20 miles. We see, then, that the earth's skin is six times thinner than the skin of this ball."

"No, father," said Jack, "it is only three times as thin."

"How do you make that out?"

"In taking the diameter of the earth as 8000 miles, you have measured right through from outside to outside, and so included the thickness of the skin twice over."

"Oh, yes, I see where I am wrong, Jack! I should have remembered that each skin was 20 miles thick, so we must divide the 8000 miles by 40."

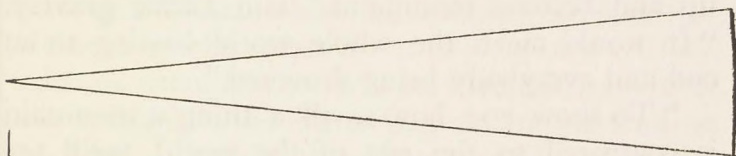
"We find, then, that the earth is 200 times

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thicker than its skin, while the ball is only sixty times thicker than its skin.

"Starting outward from the centre of the earth, we should pass through 3980 miles of material heated many times hotter than molten iron (though kept solid by the enormous pressure upon it), and 20 miles of rock before we came to the surface.

"Our earth is just like this burst ball. Its skin is too big for it. This is not because any of the liquid inside it has escaped—but because the



Centre of the earth. 3980 miles of molten material. Crust (20 miles thick).

whole of the earth is growing colder, and when any body grows colder, it shrinks, and folds itself into a smaller space. Some parts of the earth's surface are always falling in, and when they fall below the level of the sea, the sea rushes in over them to fill up the hollow. When I push in any part of this ball, you see it rises up in another part, and in the same way some parts of the earth's surface are being raised up at the present time, because other parts are being crushed in. If such a disturbance of the earth's surface caused the whole of Europe and the whole of

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Africa to sink below the level of the sea, and if all the bottom of the Atlantic Ocean were to rise up and become dry land, even this tremendous change would not be as great a change in comparison to the size of the earth, as if I were to press in the skin of this rubber ball with my finger ever so slightly. Part of South America is still rising out of the sea."

"I cannot believe that the mountains could sink under the sea, and the bed of the sea rise up and become mountains," said Lizzie gravely. "It would mean the whole world coming to an end and everybody being drowned."

"To show you how small a thing a mountain is compared to the rest of the world, we'll try an experiment. Here is the dining-table that ten of us sat round for dinner. If we imagine the world to be as big as this table, how high do you think the highest mountain in the world would stand in comparison to the height of the dining-table?"

Lizzie glanced out of the window to the top of Auchincairn and remembered their long climb yesterday until they stood on the peak. They seemed to be standing on the roof of the world as they looked down over the moorlands into the lower hills covered with grass and traced the river winding through the valleys, down, down,

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into the Solway Firth. She knew the hill was about 2500 feet high, and that Mount Everest, the highest mountain in the world was 30,000 feet high. What a terribly high mountain Mount Everest must be, if it were equal to twelve of her mountains piled one on top of the other.

"Now that you all have had time to think of it," said the doctor, "will you each place some article on the table, to show how high you think the highest mountains are compared with the thickness of the earth."

Lizzie thought that Mount Everest must be at least as high as the water jug, so she put that on the table. Ronald thought that might be too high, so he placed a tumbler. Jack guessed from the way the doctor was smiling that the other two were very far wrong, so, determined to be safe, he picked out a biscuit and laid it by the water jug. Then they asked the doctor what he was going to put for the height.

"Well, I don't know, children, but I think I will put it a great deal lower even than Jack. The height of the highest mountain above the sea as compared with the thickness of the earth, is about the thickness of a postage stamp, as compared with the height of the table."

"Oh, father, surely that cannot be!" cried Jack.

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"Let's see who is right," said the doctor. "Which is the highest mountain in the world, Lizzie?"

"Mount Everest."

"And how high is that?"

"I don't know," said Ronald.

"Then get the geography book and look it up."

"The book says Mount Everest is 29,872 feet," said Lizzie.

"Now, let us see what is the height of the table. Bring me a foot-rule, Jack, and we will measure it. You see it is about 2 feet 6 inches, that is, 30 inches high. Now, Ronald, what is the diameter of the earth?"

"Eight thousand miles," he answered. "But how are we to measure the thickness of a postage stamp? It has no thickness at all."

"There are a great many instruments which will measure much finer distances than that," replied the doctor. "But I will show you a very simple way. Here are five shillings' worth of postage stamps, that came in a letter this morning. You see the whole sixty of them, laid on the top of each other, are about half an inch thick; then one postage stamp will measure about the hundredth part of an inch in thickness. Now we have a sum in simple proportion; if the height

The Earth's Crust

of a postage stamp is one-hundredth part of an inch, and the height of the table from the floor to the top is 30 inches, what is the proportion of the thickness of the stamp to the height of the table?"

Ronald took a piece of paper and worked it out, and found it was one three-thousandth.

"The table, then, is three thousand times as high as a postage stamp."

Jack had been very busy scribbling figures on a notebook, and now his face became radiant.

"I think you are wrong this time, father," he said, triumphantly. "Mount Everest is, say, 30,000 feet high—that is 10,000 yards. There are 1760 yards in a mile, and 10,000 yards comes to about five and a half miles. Five and a half miles goes into 8000 nearly 1500 times, so that Mount Everest would be twice the height of a postage stamp."

"Let me look at your figures, Jack."

"Yes, you have caught me making a mistake this time. The highest mountain, then, is as high as two postage stamps instead of one. You have shown the true scientific spirit, Jack, in checking my figures for yourself. A scientist never lazily accepts any statement, when he has the means of testing its truth for himself.

"You see what a very little movement it would require to raise one corner of the table the height

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of a postage stamp, or even the height of two or three postage stamps above the rest of the table. So that if the table were covered with water the corner that was raised would become dry and the water which was upon it would run off to some other part of its surface ; and if another part were raised and the first corner were to sink again, the water would run back once more and leave the other part dry.

So you can see that, compared to the size of the earth, the amount of rising or sinking of the earth's crust which is needed to make the sea dry land, and to bury the mountains under the sea, is very small indeed.

"If the sea were to rise 1000 feet, or even 500 feet, you would be surprised to find what a small part of Europe would be left. But one thousand feet is such a small part of the earth's thickness, that it is very difficult to give you any idea of it. The whole history of the world would have been different if the North Sea had been thirty yards shallower (see map, page 78). Then England would have been joined to Europe in two or three places, and would probably never have existed as a separate nation. It is almost impossible for us to think of what the history of Europe would have been if England and Scotland had not been separated from the mainland.

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“In comparatively recent times, considering the age of the world, the Thames and Tweed were tributaries of the Rhine, which flowed through the North Sea Plain and cut out a deep estuary round Scandinavia, where the water quite close to the shore is still as deep as the Atlantic Ocean.

“The average height of the land above sea-level is 2300 feet, or rather less than half a mile. If I had a balloon big enough to reach from the floor to the ceiling of this room, say ten feet in diameter, and I wished to gum a sheet of paper on it, so as to represent the surface of the land as raised above the level of the sea, the paper would have to be less than the one hundred and fiftieth part of an inch in thickness. If you wished to show the depth of the oceans as compared to the thickness of the earth, you could breathe on the polished top of the table so lightly as just to dim the polish, and then the thickness of that film of moisture compared with the height of the table would stand for the depth of the oceans compared to the thickness of the earth.

“We are so often told that the sea covers three quarters of the surface of the earth, and that the dry land is only one quarter, that we need to be reminded sometimes that after all the sea is not deep.

“I want you to get thoroughly accustomed to the

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idea of the land sinking below the level of the sea, and the sea bottom rising into mountains, as this alternate rising and sinking of the earth's surface is a most important fact for students of geology. The slow progress that the science of geology has made, although all the facts on which it is founded have been lying bare, staring men in the face for thousands of years, is mainly due to the mistaken idea that the land has always been separate and distinct from the sea.

"In reality, land and sea have been moving up and down, as if playing sea-saw with one another, ever since the world came into existence.

"Greek and Roman writers had observed fossil sea-shells in the rocks on the tops of mountains, but while they saw at once that the fossil shells were the same as the shells on the seashore, it never occurred to them that the sea had once rolled over these mountains, and they tried to account for the fossil shells by all sorts of strange theories.

"Leonardo da Vinci, the painter of the famous picture of the Lord's Supper, who was a great civil engineer as well as an artist, discovered hundreds of fossils during his excavations. He was the first to see their true nature, but nobody would believe him or accept his explanations. Men clung on so determinedly to the idea that





78

Map of Western Europe if sea were to sink 300 feet. The area shown white would be dry land. Note the two bridges of high land which would connect England with the Continent supposing that the sea sank 100 feet only. These are lightly shaded within dotted lines.



79

Submerged England. The shaded parts represent land above the level of 300 feet. This only appears above the water.



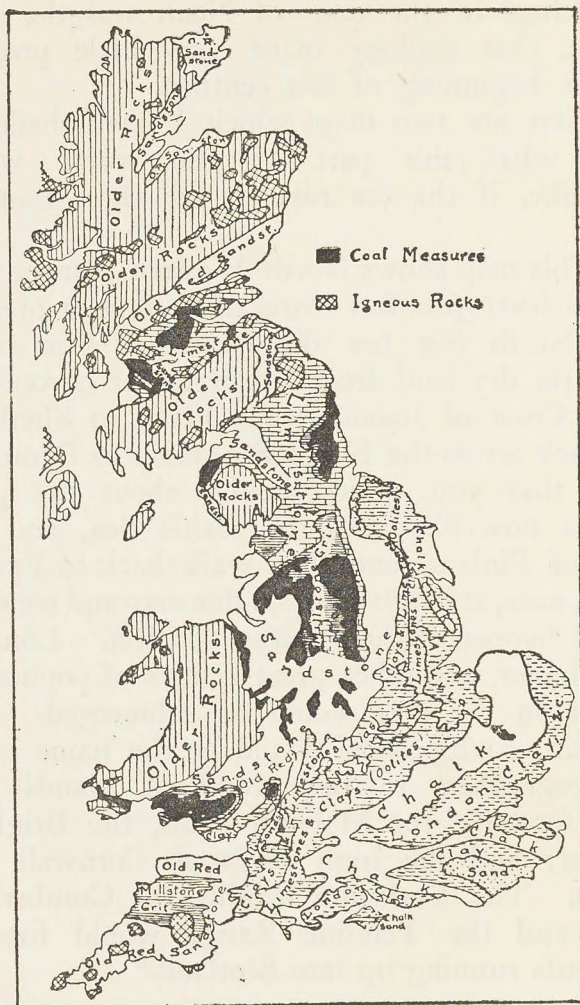
The Earth's Crust

the deluge in the time of Noah was the only deluge, that geology made very little progress till the beginning of last century.

"Here are two maps which I have shaded to show what this part of the world would look like, if the sea rose or fell three hundred feet.

"This map shows North-Western Europe with the sea-level 300 feet lower than it is at present. The North Sea has disappeared. You could walk on dry land from Spain to far beyond the West Coast of Ireland, then north to Shetland, and back across the North Sea Plain to Denmark. After that you could wander about the great valleys now filled by the Baltic Sea, and the Gulf of Finland, and then walk back to France. Look, now, at England upon this map and see what would happen if the sea rose 300 feet. London, Manchester, and other great centres of population shown on the map would be submerged. The 'English Archipelago' would be the name given by geographers to the group of islands that were formerly the Malvern Hills, the Brighton Downs; and the high lands of Cornwall and Wales. The Yorkshire heights, the Cumberland Hills and the Pennine Range would form a peninsula running up into Scotland."

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Geological Map.

Chapter the Sixth

The Eurafrian Continent

*I am the Sea! I hold the land
As one holds an apple in his hand;
Hold it fast with sleepless eyes,
Watching the continents sink and rise.
Out of my bosom the mountains grow,
Back to its depths they crumble slow.
The iron cliffs that edge the land,
I grind to pebbles and sift to sand;
I comfort the earth with rains and snows
Till waves the harvest, and laughs the rose.
Flower and forest, and child of breath
With me have life—without me, death.
The earth is a helpless child to me.
I am the Sea!*

CHARLOTTE P. STETSON



E learn at school that the old world is divided into three continents — Europe, Asia, and Africa—which are inhabited respectively by white, yellow, and black people. In the Sunday

School, we hear so often that the heathen in his

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blindness bows down to wood and stone, that we think ourselves entirely different from and a good deal superior to the inhabitants of Asia or Africa, whom we consider heathens."

"It is always difficult for us to realise that this division into Europe, Asia, and Africa is purely artificial, and very modern. The early inhabitants of Northern Africa were just as white as you are. Geology has proved, what the study of the races and languages of the world had led us to suspect, namely, that the Northern part of Africa once formed part of Europe, and was separated from the Southern part of Africa by a sea which connected the Atlantic with the Indian Ocean, and covered the great Sahara desert.

"To go back again to our simile of the wobbly india-rubber ball, we may say that in quite recent times (always speaking geologically) some movement inside the earth caused the outside skin to wobble, with the result that the Sahara desert was raised out of the Atlantic and Indian Oceans. To compensate for this rising of the earth's skin under the Sahara, there had to be a sinking somewhere else. The land which formerly extended between Southern Europe and Northern Africa sank and the Atlantic Ocean flowed into this depression and formed the Mediterranean Sea, as we now know it.

The Eurafrian Continent

“The Atlas Mountains in North Africa are geologically the same as the mountains of the rest of Europe. The sea between Spain and Africa is still shallow. The peninsula of Italy is a half drowned range of mountains, which ran from the



Eurafrian Continent. Outlines of the Eastern Hemisphere in the Early Quaternary (after Brinton). The present continents are shown in dotted lines.

northern to the southern part of the Eurafrian Continent. The islands of Sicily and Malta are parts of this range, still above water. The terrible earthquakes which recently devastated the country round Messina, and the renewed activity of Mount Vesuvius, are further proofs of the

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newness and instability of this part of the earth's crust.

"If you look at the map of the Eurafrican Continent, and compare it with the submarine



Relief Sketch of Malay Archipelago, Australia, and adjacent islands, showing (in white) the shallow seas surrounding them.

plateau of Australasia, and the sketches showing the effect of the sea round England falling or rising a hundred yards, you will understand how it is possible for geologists to reconstruct the country now lying under the Mediterranean Sea.

The Eurafrian Continent

"The Black Sea and the Caspian were the southernmost bays of the great Northern Ocean, which rolled over the plains of Russia and Siberia. For a considerable time after man had appeared on the earth, India and Arabia were islands, which have since been united to the mainland by banks of sand and gravel, brought down by the great rivers and deposited when they reached the sea."

"The early home of all the white races was somewhere to the North of Africa. Probably it is now lying beneath the waters of the Mediterranean, and this may account for the fact that every one of the Aryan nations, from Ireland to India, has its distinct traditions of a flood which destroyed the ancient world."

"Plato's description of the lost island of Atlantis, which is still perpetuated in the name 'Atlantic,' has had a fascination for writers and thinkers ever since it was written. Ingenious commentators have tried to locate it in almost every country in the world, and there is no doubt it stimulated many of the navigators and discoverers of the sixteenth century. For centuries Plato's Atlantis was regarded as mythical, and even Dr Jowett, who has given us the best translations of the Dialogues, says in his introduction to the Critias, 'No one knew better than Plato how to invent a noble lie.'"

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"This criticism is, I think, quite unwarranted, and most unfair to Plato, who undoubtedly tells the story seriously, and regards the journey of Solon to Egypt, and his meeting with the old priest at Sais, as actual historic fact.

"This conversation, which took place over 2500 years ago, beside the banks of Father Nile, is the most dramatic recorded in literature.

"Solon, the first law-giver of Athens, and the wisest man of ancient Greece, had journeyed to Sais, the capital of Egypt, and the most learned city in the world. There in the temple of the goddess Neith, he had been speaking of the splendours of Athens, and had traced the genealogies of her rulers right back to the time of the Deluge, to Deucalion and Pyrrha who escaped from the flood in an ark when all other mortals perished.

"Hand me down that dark red book, and I'll read you what the old priest said to the Greek philosopher, as we in our own day are just as apt to assume that we know everything, and to despise the wisdom of older nations.

"'O, Solon, Solon, you Hellenes are but children and there is never an old man who is an Hellene.'

"Solon hearing this said:—

"'What do you mean?'

The Eurafrian Continent

“‘I mean to say,’ he replied, ‘that in mind you are all young; there is no old opinion handed down among you by ancient tradition, nor any science which is hoary with age, and I will tell you the reason of this. There have been and will be again many destructions of mankind arising out of many causes.

“‘The greatest have been brought about by the agencies of fire and water, and other lesser ones by innumerable other causes. There is a story which even you have preserved, that once upon a time Phaethon, son of Helios (the sun), having yoked the steeds in his father’s chariot because he was not able to drive them in the path of his father, burned up all that was upon the earth, and was himself destroyed by a thunderbolt. Now, this has the form of a myth, but really signifies a declination of the bodies moving round the earth, and in the heavens, and a great conflagration of things upon the earth, recurring at long intervals of time.

“‘As for these genealogies of yours which you have recounted to us, Solon, they are no better than the tales of children, for, in the first place, you remember one deluge only, whereas there were many of them.’

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“It is very remarkable to find such a distinct and emphatic statement, that ‘there have been not merely one but many deluges,’ made at so early a period in the world’s history, and I have often wondered how far the science of geology might have been advanced, if the wise men of old who founded their physical science on Plato, had only grasped this fundamental idea of the frequent submergence of various parts of the earth’s surface.

“You can read the rest of the dialogue for yourself, Ronald, and when you have learned something of geology, you may go back to old Plato, and find him interesting. We moderns are only beginning to find out how much the ancients knew, and we have in the past despised their learning simply because we ourselves did not know enough to understand it.”

“Thro’ the depths of Loch Katrine the steed shall career,
O’er the peak of Ben Lomond the galley shall steer,
And the rocks of Craig Royston like icicles melt,
Ere our wrongs be forgot or our vengeance unfelt.”

MacGregor’s Gathering.

Chapter the Seventh

Serapis

Their decay

*Has dried up realms to deserts—not so thou
Unchangeable, save to thy wild waves play.
Time writes no wrinkle on thine azure brow
Such as creation's dawn beheld, thou rollest now.*

Childe Harold, Canto IV.



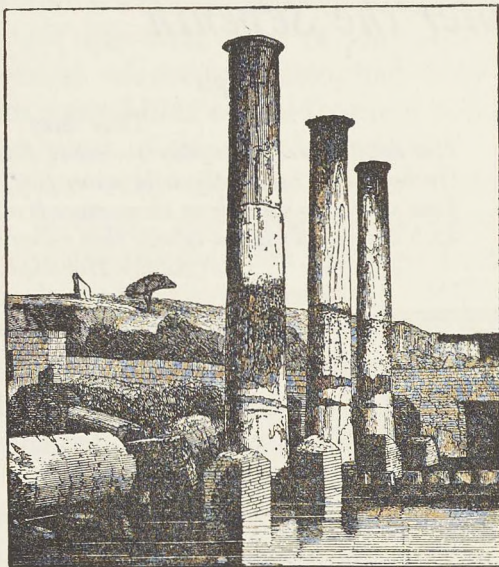
YOU will remember that we found Mount Everest — the highest mountain in the world — was, when compared to the size of the earth, only about as high as two postage stamps gummed on to the top of a dining-room table. The depth of the sea might be compared to the thickness of the film of moisture on the polished table top when you breathe upon it.

“Comparing the earth again to a large india-rubber ball, or better still to a balloon, from which some of the gas has escaped, so that the skin is slightly wobbly, we might say that the continents are the places where, owing to the skin having

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been raised a little, the surrounding film of water has run off and left the land dry.

“You should think of the earth being lightly clothed by the sea, like a boy who is wearing a



The Temple of Serapis.

very thin bathing costume with numerous holes in it, so that his bare skin appears every here and there.

“Islands are mountains resting upon plains which happen to be covered by the sea; and estuaries like the Thames or Clyde, the sea lochs

Serapis

of the west of Scotland, and the Fiords of Norway, are valleys which have been drowned by the rising of the water, or rather, by the sinking of the land below the level of the sea. In some parts of the world's surface, the land is slowly rising above the level of the water, and in other places it is still sinking. This is well illustrated by the history of the Temple of Serapis at Pozzuoli.

"That is a photograph of its ruins hanging above the barometer there.

"Marius, Pompey, and Julius Caesar (who each in their turn conquered the world, made themselves masters of Rome, and died tragically), had country houses at Baiae, and often walked beneath those colonnades, and looked out upon the still blue waters of the Bay.

"There is a road that leads from Pozzuoli round the north-west corner of the Gulf of Naples to Baiae. On the right the ground rises towards Mount Solfatara, which was once a volcano, on the left it slopes down to the border of rich land which fringes the sea.

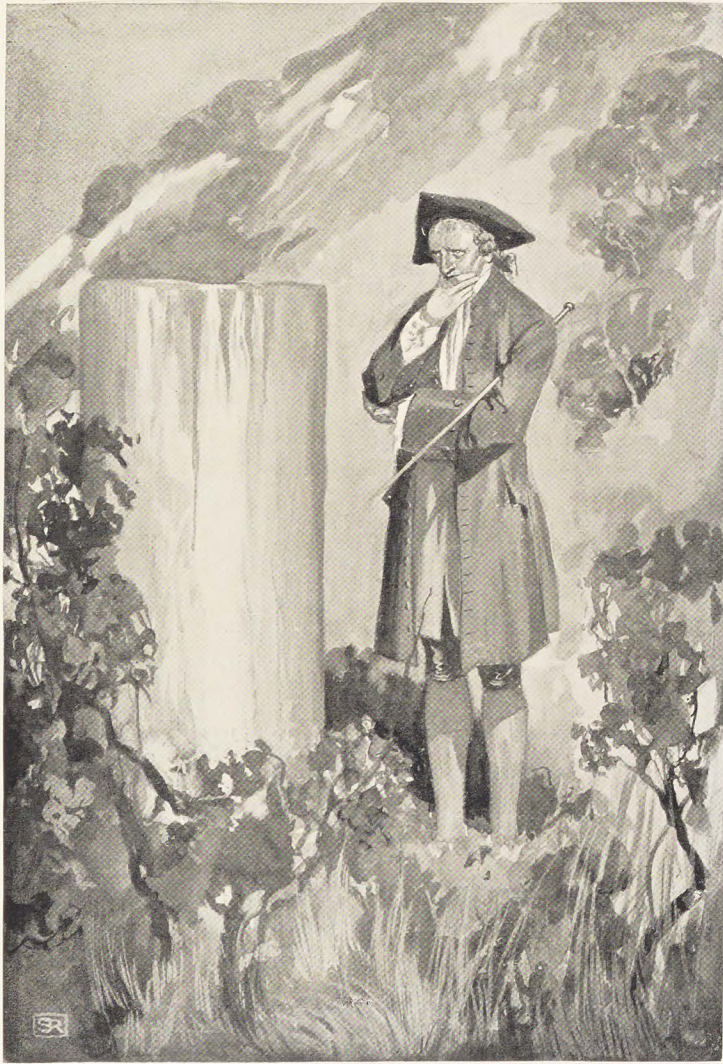
"Half way between the road and the sea, a marble column about five feet high stood among some bushes.

"There are a great many noble ruins in that district, as it was the most fashionable seaside resort

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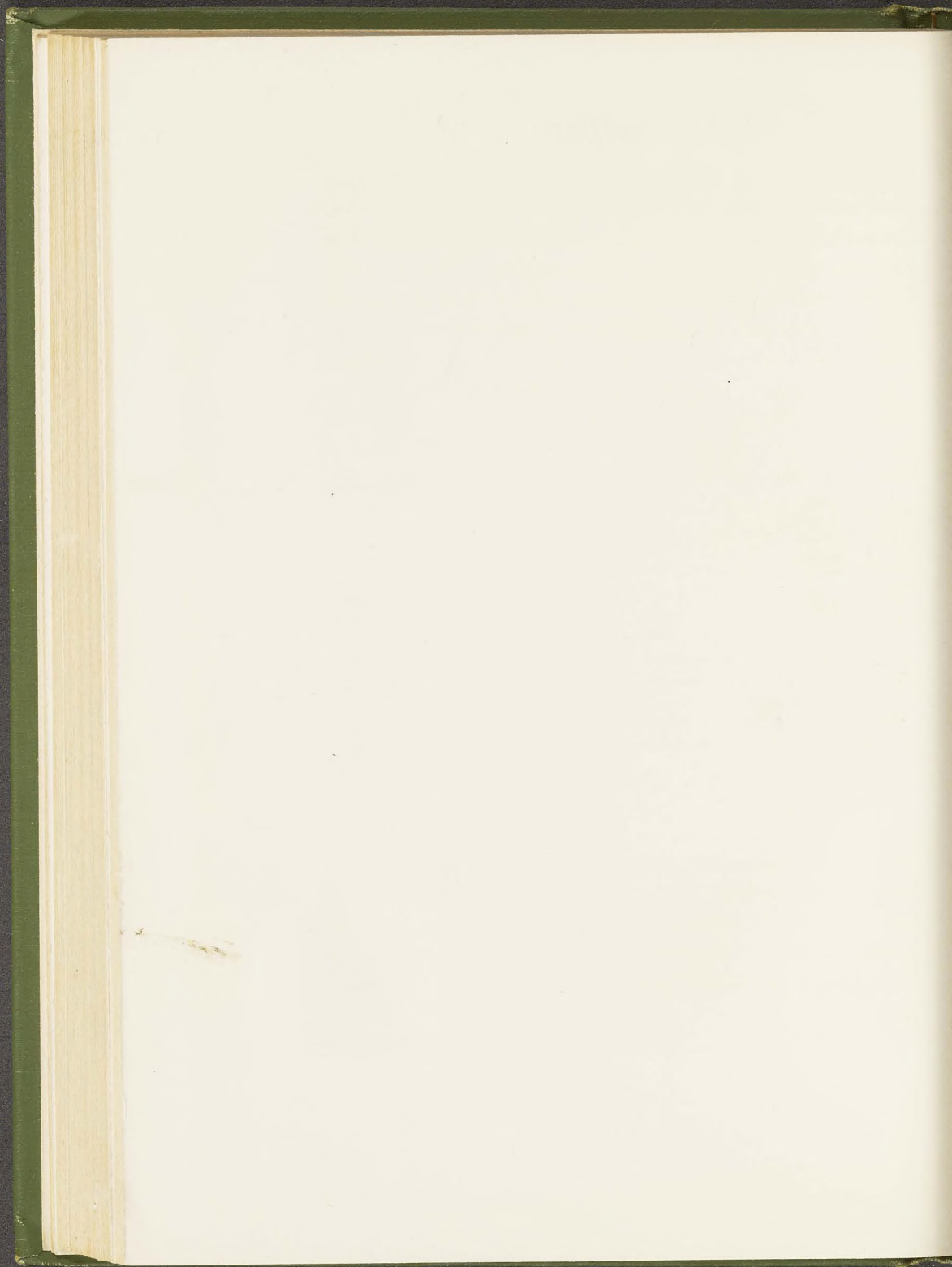
of the Romans when at the height of their power. Two hundred years ago a traveller saw the pillar. Nothing was known of any public building having existed at that place, so he wrote in his book that this fragment had probably come tumbling down the mountain from some other ruin, and had stuck in the ground with its top end up.

“The traveller was a learned man, and all the tourists were told the same story, and all believed it. In 1749 an observant stranger walked off the road, came and looked at the pillar for himself, and noticed that the top was quite level. He wandered round among the bushes and found the top of another pillar. He didn't understand how two pillars could have tumbled down a hill, and both stuck into the soil with their tops level. He poked about with his walking stick, piercing the soft ground here and there, until he struck the buried top of a third pillar. He found it was in line with the first two, its top was level with their tops, and they were all the same distance apart. Then, he said, ‘this is not the case of a pillar falling down a hill, but of a hill falling round a pillar’; and that if they were to dig down, they would discover a great temple which had been buried for two thousand years. Excavations were made, and the ruins of a magnificent temple were laid bare. It was seventy feet square and sixty feet high, the roof



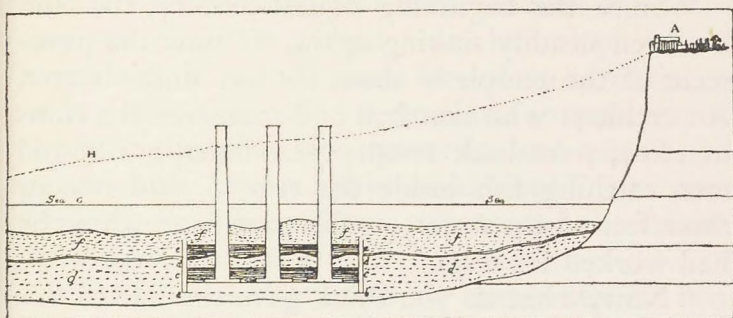
"An observant stranger looked at the pillar"

Stephen Reid



Serapis

being supported by forty-six splendid granite and marble columns. The walls were decorated with beautiful panels of precious stones. But that was not the wonderful part of the story. When geologists examined the ruins they saw it clearly proved



A Site of Cicero's villa. In one of his letters he tells us he could "catch fish out of his dining-room window."

a b Ancient mosaic pavement.

c c Dark marine incrustations.

d d First filling up by showers of ashes.

e e Fresh water calcareous deposit.

f f Second filling up by showers of ashes.

G Sea-level when lithodomus borings made.

H Level of accumulated rubbish which had fallen down mountain and buried temple.

not only that forty feet of sediment had been laid down above them in 2000 years, but that the land on which the temple was built had sunk at least five feet under the sea, and remained at that level for several hundred years. Then it had gradually

Secrets of the Hills

sunk down another twenty feet and rested there over 600 years. Finally a great earthquake raised the whole sea bottom in the district, over twenty-six feet, so that the temple once more stood on dry land.

"Since the beginning of last century, the land has been steadily sinking again, till now the pavement of the temple is about six feet under water. An architect who sketched and measured the ruins in 1814, went back twenty years later, and found men catching fish inside the temple, and two or three feet of sea water on the pavement where he had worked for days.

"Now, what do you think gave the clue to this strange history? Lift down the photograph and examine it carefully. You will see that the lower halves of the marble columns are pitted with holes. These holes have been proved to be the burrows of a small sea animal, the lithodomus mollusc. It is a cousin of the common edible mussel, about the same shape and size, and is named lithodomus (lithos = stone, domus = house), from its habit of boring a hole for itself in the rock.

"The tiny cave which the lithodomus hollows out for itself is pear-shaped, with the narrow end opening to the sea. The shell-fish sits at its front door all day waiting for some unwary little animal to drift within reach. When it has taken

Serapis

in a sufficient number of visitors, it shuts its shop, and retires to digest them.

“The enterprising founder of this lithodomus colony discovered that the tall slender marble pillar standing by itself in deep water, was a capital site for doing business, because far more tiny sea creatures drifted near him than would have done, if he had been located in an ordinary rock. He and his descendants industriously occupied the place for centuries, and pitted the pillars with innumerable holes, until the unthinking earth heaved up and hoisted the temple ruins right into the air.

“Sir Charles Lyell tells us that when he first examined the ruins, most of the pear-shaped holes had shells in them. You could put your finger in and move the shells about, and feel them all over, but you could not get them out of the hole, because the narrow entrance was not big enough to let your finger and the shells come out at the same time.

“Buzzing crowds of tourists have long since fished out all the shells with bits of wire. The molluscs were such convincing proof that the pillars had actually been standing under the sea at no very distant time. The tourists took the shells home to show to their friends when they told them the wonderful story.

Secrets of the Hills

"Marble is a hard crystalline rock, and the lithodomus is a flabby little animal without a single bone in its body. How does it bore its cave?"

"I don't know," said Roland, "unless it scrapes it out with its shells."

"It can't do that, Ronald, because the mussel shell is much softer than marble, and wouldn't make any impression upon it."

"How do you know that, doctor?"

"If you will think a minute you will see that it must be. The shell is an animal secretion composed of lime, which the mussel has taken out of the water, and is built up of thin layers like the pages of a book gummed together."

"Marble is limestone rock, originally formed of shells no doubt, but it has in addition been baked intensely hard by hot lava flowing near it while it was buried in the depths of the earth. There are many other things which make it quite impossible for the mussel to cut the rock with its shell."

"Then how does it carve out its cave, doctor?"

"You must remember that the mollusc is an animal just as you are, but it wears all its bones outside its flesh, while you have yours inside. You would admit this is true of a crab; so you

Serapis

can't deny it of a shell-fish. Like you, the mussel eats other animals and plants, and breathes oxygen which it finds dissolved in the water. You are constantly breathing out carbonic acid gas, and the mussel does the same. The carbonic acid gas acts on the marble and gradually softens it, then the mussel rubs off the softened rock with its "foot" or tongue and constantly enlarges its home. One result of this is that the lithodomus is imprisoned in the rock for life, like the old monk who had broken his vow, and was built up alive into the wall of the monastery and fed once a day through a hole in a stone. The mollusc, who has so indelibly written for us the strange history of this part of the world, which otherwise we should never have known, is in a much worse position than the mouse that squeezed its way through a small hole into the sugar tin, and then ate so much that it couldn't get out again. Still, this imprisonment doesn't seem to worry the mollusc, for the fossil records show that it has gone on for millions of years just living and boring its holes into the rocks in the same way as it does to-day.

"Excavations made in the centre of the temple have revealed a beautiful mosaic pavement five feet below the level of the present one, which must have been put in after the building had sunk

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so far that the old mosaic was covered by the sea water and a new floor was needed to enable the temple to be used again.

"The fact that these tall fragile pillars have remained standing for over two thousand years, while the rest of the building has peacefully decayed away, shows that there has been no violent shaking of the ground.

"Built on the shore overlooking the Bay of Naples, the temple gradually sank along with the surrounding country, till the waves crept up to it and lapped at its foundations. Year after year the land sunk lower and lower. The tides flowed in and out among the bases of the columns, and the little sea animals lived and died and left their shells sticking in the pillars, where we see them to-day. The columns are pitted with these holes up to a height of twenty-six feet from the floor, and as they can only have been bored by the lithodomus when the pillars were under water, these holes prove that the temple must for a considerable period have been sunk for twenty-six feet under the sea.

"The land rested there under the sea for centuries till disturbed by the great earthquake in 1198. Then, again, about the year 1538, the crust of the earth began to heave, and the ground gradually rose out of the sea. The subterranean forces pushed it up and up till once more the

Serapis

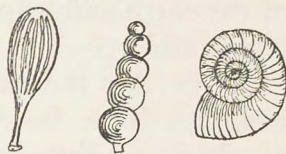
drowned and buried temple stood on the seashore and overlooked the Bay.

"These earth movements were so gentle, and such a large area of the land moved at once, that the tall slender pillars stood undisturbed. The holes in the marble show the fall and rise of the land between these two dates. Recent measurements prove that the country is once more sinking at the steady rate of nearly an inch a year.

"I often look at those three lonely columns and wonder how many worlds they are the survivors of.

"Millions of years ago, in the deep blue ocean, tiny little animals called foraminifera (that even under the microscope are a mere speck of jelly) lived in the sunshine on the top of the warm water. Year after year these foraminifera died, and their tiny shells fell down like snowflakes through the clear still water, till they covered the bottom with a bed of ooze a hundred feet thick.

"As age succeeded age, great mountain ranges on the adjacent continent were gradually eaten away by the rain drops and carried down the rivers grain by grain, and dropped further and further out till they covered up the bed of shell ooze lying on the floor of the ocean to a great depth.



Foraminifera shells
greatly magnified.

Secrets of the Hills

"It is impossible to calculate how many millions of years the tiny shells of the foraminifera, now crushed and changed into limestone, lay buried under the miles of newer rocks that were thus heaped up above them. Thousands of feet above these unborn mountains, the ocean waves danced in the sunshine, and the rivers came bringing down their constant tribute of sand. These beds of newer rocks lying on top of the limestone acted like great blankets, which kept in the internal heat of the earth and helped to convert the crushed shells into marble.

"One day the skin of the earth gave a great wobble. The floor of the ocean slowly rose hundreds of feet into the air, and lay stretched out under the sun as a wide continental tableland.

"While man was slowly rising in the scale of being, the rivers were cutting their valleys out of this new continent. In the course of untold ages one of these rivers had carved its channel down through all the layers of the newer rocks, until it cut into the bed of marble lying in the bottom of its valley.

"At length man wandered up the river valley, found the marble rock, and cut out these pillars for a temple to his god Serapis. The old foraminifera shells were again exposed to the sunshine.

"That ruined temple, with its pillars still

Serapis

standing, is a good picture to look at when you feel worried and cross. Marius and Pompey and Julius Cæsar convulsed the whole world between them two thousand years ago, and each in his turn thought himself the most important being in the universe; yet to-day, you and I are more interested in the little sea animals that bored holes into their temple after it had sunk beneath the sea.

“Serapis was the Græco-Egyptian god of the under-world. It is very appropriate, therefore, that his temple should so strikingly exhibit the working of subterranean forces.

“If one of the old high-priests could rise from the grave where he was laid two thousand years ago, we can imagine how triumphantly he would prove the divinity of his god, and his special care for his own temple, from the fact that although all the towns in the neighbourhood have been destroyed by earth movements many times over, yea, though even the sea and land have changed their places, the pillars of Serapis still stand.

“There is, however, a natural explanation. This temple for the worship of the ruler of the dead was built at Baiæ, because that district had, from time immemorial, been associated with strange manifestations of subterranean power. The grotto of the Cumæan Sibyl, the world-famed grove of

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Hecate, the goddess of ghosts and witches, and controller of the future; and the awful lake of Avernus, filling the crater of an extinct volcano, whose dark and sulphurous waters gave entrance both to the under-world of Homer, and the Elysian fields of Virgil; were all within three miles; and the whole district seemed consecrated to the service of Pluto.

"A modern geologist would point to Mount Vesuvius across the Bay and calmly lecture us on the theory of volcanoes.

"During an eruption such a large quantity of melted rock would be spouted out of the mountain, that a great hollow would be left under the earth where the erupted material came from. The overhanging crust of the earth would eventually settle down into the empty space. This would cause the surface of the earth immediately above it to sink also, and the sea to flow over it. Before another eruption, another great mass of volcanic material would have collected beneath the crust of the earth near the volcano. This would swell and float up the over-lying rocks, and the surface of the earth would rise again, only to sink once more after the eruption."

Chapter the Eighth

Gold Digging



LD Willie Grant knows more about gold digging than anyone else here," remarked the doctor one morning. "If I were you, I would ask him to go with you to the Windgates.

Bill will show you where he lives. Tell him I sent you, and he will take you if he is well enough."

Old Willie lived by himself in a cottage in the Cross Row. He had a round full-moon face, weather-beaten and scarred, with a fringe of curly white hair round his brow from ear to ear, and a shaggy white beard and whiskers. In answer to Ronald's request to be allowed to see his specimen of gold quartz, he handed him a white stone about the size of a brick. It had yellow patches on its surface, and was streaked with brown.

"If you take it over to the window you'll see the gold; it goes right through in that vein.

Secrets of the Hills

Yes, I found it myself upon the Lowther Hills. I was climbing a scaur after a heavy rain. A bit of the bank had fallen away, and I noticed this white brick lying at my feet. I took it down to the burn and washed it, and then I saw the yellow gold grains glistening in the sunlight, and knew there must be plenty more gold quartz where that came from. So I went up the bank of the scaur, and scraped away the gravel with a stick and my hands, rubbing off the mud with some wet grass. It was a quartz vein right enough, about two feet wide, and just exactly the same colour as the quartz you have in your hand."

"I wish you would tell me where that gold vein is," said Ronald; but the old man shook his head.

"I've promised to show it to the doctor, some day before I die, but I'll never show it to another living man. Here is some of the gold I have been getting at the Windgates," he said, producing a small round medicine bottle with some dull yellow grains at the bottom. Ronald took the little bottle and shook it. The yellowish brownish powder did not look like gold at all, and it was only when he held it up in the beam of sunlight, which streamed through the little four-paned window, that he saw the glint of the golden sands for which men have dared and suffered so much.



Photo W. H. Scott, Leadhills

The Windgates burn, where Ronald washed for gold, enters the main valley at the small shepherd's house in the centre distance.



Gold Digging

"I havna' been at the gold for a good while now," old Willie went on; "but seeing you are so keen, I will go over to Windgates with you, and show you where to find it."

So the bent, weather-beaten old miner, with a bright-faced boy on each side of him, walked through the main street of the village; and past the Crush Mills, where the quartz rock containing lead ore is broken up, and the lead taken out to be smelted.

Crossing the moor, following a sheep track amongst the heather, they stopped on the brow of the hill, and looked down on the long valley winding away up into the mountains.

"That's the Windgates," said old Willie, "and the third burn up on the left hand side is where I was working the gold. I have a barrow and some troughs and tools there, hidden in the heather.

"You see those heaps down at the side of the water? They have all been worked for gold already, so there is no use in seeking it there. The best place to search for it is in the bed of the burn itself, as gold is very heavy and always sinks to the bottom. When I was a lad, we used to get lots of gold in the summer time, when the burn was nearly dry. We made a small dam and kept back the water; then we picked out all the

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stones, stirring up the sand and mud with a stick, or kicking it about with our feet, so that the water might carry away the mud and small gravel until there was just a little skin of dirt on the rock.

"Next we shut off the water until it was a tiny trickle, and going down on our hands and knees in the burn, we rubbed the fine dirt till it floated away. Then, with our backs to the sun, we saw the gold grains lying on the rock, and picked them out. Many a hundred grains we have gathered that way, and once I found a nugget as big as a small bean. In South Africa the miners quarry out the quartz rock, smashing it into little pieces, and grind it into powder, then they use mercury and other chemicals for taking the gold out of the crushed rock."

"But if the quartz that the gold is found in is so terribly hard, how does it get washed away by the rivers?" asked Ronald.

"Well, you would not think that rain and wind and weather could eat away solid rocks, but they do. When the sun shines on the surface of a rock, the heat expands the top layer. The one beneath this does not get so much heat, and it does not expand in proportion. This causes the topmost layer to have little cracks in it. The rain drips into these cracks and makes them bigger, and in the winter, when the frost comes, the

Gold Digging

water left in them is frozen. Ice, as you know, takes up more room than water, so this makes the cracks wider and wider, till pieces of rock break off altogether. Frost is the strongest thing in the world for breaking rocks."

"I was asking the doctor the other day," said Ronald, "how the Egyptians managed to cut out the great blocks of stone which they used for the pyramids, and for their huge statues. I could not understand how they were able to hew them out of the solid rock, because they had no dynamite or gunpowder such as we have. He told me that when they found a small crack in the rock, they would hammer into it wedges of wood that had been made as dry as possible, and then crushed down till they were half their usual thickness. When the crack was filled with these wedges, water was poured over them, and as the wood soaked up the water it began to swell. The strength of the swelling wood was so great, that at last it forced open the crack, and split off a great mass of rock."

"I have seen the same thing done myself," said old Willie, "when I was working in a quarry where they sometimes wanted a large block of stone for a special purpose."

"The Egyptians used quicklime, too, for the same purpose as we do here in some coal mines

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where there is much danger of fire, and explosives of any kind cannot be used. You have seen men mix lime when they were building, and noticed the great clouds of steam that were given off when the water was poured on to the lime shells.

"I once worked in a coal mine," he continued, "where they split the coal with the ordinary beans the horses ate. They bored a hole, filled it with beans, poured water into it, and then plugged up the hole and left it. The beans began to sprout, and their strength was so great that they split open a huge block of coal.

"I wonder," said the old man, musingly, "if you have ever thought what a terribly strong thing life is? Look at a pea. Nobody ever thinks that a pea has the power in it to split a rock, but it has. If it is kept moist and fairly warm, it will begin to sprout, and the young plant will split its shell and almost anything that tries to prevent it from opening. Peas are still used when men want to split anything that is very brittle, and which they are afraid would be broken altogether if they tried to lever it open with a chisel or in any other violent way.

"Did you notice a rowan tree, just this side of the bridge over the river, on the road up from the station?

"It grows from the very centre of a big granite

Gold Digging

boulder. I used to look at it and think what terrific power there is even in a little seed.

"No one ever planted that rowan tree in the middle of the boulder. Many, many years ago there was just a small crack in the top of it, and a little yellow seed out of a red rowan berry was dropped by a bird into it. In the spring the seed began to grow, and sent a tiny rootlet down further into the crack, and a little stem with two green leaves stretched itself up to the sunlight. The tiny green leaves drew strength from the sun, and took food out of the air, and sent nourishment down to the root, all through the summer. The autumn winds blew dead leaves into the crack, which decayed, and kept the root warm, and made fresh soil for it; and the tiny rowan tree went to sleep for the winter.

"Next year the young tree sent up three or four more leaves; and they too stretched out their hands to the sunshine and drew in strength, and took food out of the air, while the little white roots groped their way down into the crack in the stone, and grew longer and stronger, soaking in the water and storing up nourishment for the tree.

"I do not know how many years this went on, for the old schoolmaster says that the rowan tree was there when he was a boy, but the crack was so narrow that he couldn't get his hand into it.

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Now its trunk is thicker than my thigh, and you can see its roots going right down through the crack into the ground, outside the stone altogether, and the top of the crack is over a foot wide."

"But how does the gold get out of the rocks and into the sand at the bottom of the rivers?" asked Ronald, his mind still bent on gold digging.

"The quartz rock which contains the gold," replied old Willie, "is found in narrow veins which fill up what were once open cracks in the older rocks. This gold quartz vein is so much harder than the other rocks, that the wind and the rain and the frost cannot eat it away. The rocks on each side of it are softer, and as these are worn away, the gold quartz falls down and is left in lumps on the hill-side. When the winter floods come, the pieces of quartz are carried down by the rushing water into the bed of the mountain torrent. They are knocked against the other rocks and boulders there, and smashed to atoms. The small particles of gold drop to the bottom, and the rest of the rock, being lighter, is carried away by the river.

"Gold is found in a purer state than any other metal. One grain of gold will readily unite with another grain of gold, but it will not unite with anything else. Two pieces of almost any other metal have to be heated to melting point before they will

Gold Digging

unite into a single piece of metal. Two bits of pure gold can be made into a solid piece by pressing them together. This is why gold is used for filling holes in our teeth. Small pieces are put into the hole in the tooth one after another, and then they are gently hammered into a solid piece of gold which completely fills the hole. When the grains of gold, and sand, and bits of rock are being tumbled over one another along the bottom of the river by the force of the water, if one grain of gold knocks against a grain of sand, it will not stick to it; but if it hits another grain of gold they both stick together. The united grains will refuse to keep company with anything except other gold grains. The gold grains stick together whenever they are compressed.

“Nothing will induce a grain of gold to unite with a grain of sand or of any other mineral. The more the little group of gold grains are knocked and banged about, the closer they stick together. This is why gold rules the world to-day.

“Several grains of gold unite to form a nugget. One nugget is knocked up against another in the jumble and rumble of the stones that are being hurled along the bottom of the river, until the two nuggets are joined into a larger one.

“Long, long ago, one hot summer day, a savage,

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stooping to drink at the river, sees the little yellow stone and picks it up. It looks different from all the other pebbles. He wonders what it is, and what it is like inside. He tries to break the nugget by laying it on a rock, and hitting it with a stone. It won't break; but flattens out. It glitters in the sunlight. The savage hammers out the nugget into a long strip, and fastens it as a gold band round the handle of his axe.

"From a few small lumps of gold, one of our forefathers made a finger ring, and another a hair ornament. So, away beyond the dawn of history did the reign of King Gold begin.

"These little gold nuggets were searched for, and made into various ornaments for savage princesses. It was the gold in our brooks that brought the Romans to Scotland. They heard about it from the Gauls. In itself, gold is a soft useless metal. One grain of gold can be made to cover 50 square inches of surface, or drawn into a wire 500 feet long. It is, however, not nearly so useful as iron. Yet we worship gold and despise iron.

"But we came here to dig for gold, not to talk about it, so we will go back to the gold grains broken out of the original gold reef.

"All this valley was once the bed of a river in which gold quartz rock was being smashed to bits

Gold Digging

by the raging waters, and the grains of gold were dropping to the bottom. Gold is nineteen times heavier than water and seven times heavier, bulk for bulk, than the rock in which it is found. "That is why the gold grains are left lying in the bed of the river, when all the rest of the broken rock is carried away by the running water.

The breaking up of the gold quartz rock happened very long ago, and since then several layers of gravel, stones, and mud have been brought down by the river, and left here in its bed, so that now we find them lying one on the top of the other. You will understand it better if you look at the bank, at the side of this waterfall.

"Here is the original rock, and here, in the bank of the stream, you can see the gravel, the sand, the mud, and the large stones lying one above the other. Then you have the yellowish earth; above that, the peat, and the soil that the heather is growing in.

"Before we get to the gold we must dig away the heather, the peat, the soil, the yellow gravel, the brown sand, and the grey gravel, until we come to a yellowish-reddish-brownish layer, and the grey stones beneath it. Amongst the grey stones that are lying on the top of the solid rock we shall find the grains of gold."

Chapter the Ninth

The Bill-Ronald Gold Mining Company Limited



FOR the rest of the evening, Ronald and Bill could think of nothing but their gold mine, and they determined to do everything in the same way that the gold-seekers do in California and Australia.

The garden tent suggested camping, and the doctor agreed that they should take it with them, with food for three days, and live out in the hills, like real gold miners.

Next morning the tent, with waterproof sheets and blankets, four loaves and a frying pan, some bacon, tea, and butter, picks and shovels, bottles and troughs, and two big magnifying glasses to look for the gold with, were all packed into the cart, and the doctor's household turned out to give a good send-off to the adventurers.

"We must have a proper name for the 'Claim,'" remarked Ronald when they had started, "for it

The Bill-Ronald Company

might turn out to be a real gold mine, and make our fortunes."

After great discussion they formed the "Bill-Ronald Gold Mining Company Limited."

"Maybe you will make a fortune," said the driver of the cart, "for many a barefooted boy from Leadhills has made his in California and South Africa. There is no doubt the gold is here, and no reason why you should not find it."

"My brother is working in California, where they go in for hydraulic mining. A stream of water under great pressure is directed against the bank of gold-bearing gravel, and in this way one man can get through a thousand times as much stuff as he could by the old-fashioned way of washing it barrowful by barrowful."

At length they reached the Windgates, and the carter helped them to carry the tent and other heavy things up to the spot they had selected for their camp.

"We had better put the tent up now," said Bill, after they had picnicked amongst the heather. "We have a lot to do before it grows dark."

A level spot was chosen and cleared, the tent pole was persuaded to stay upright long enough to get the ropes fixed, the tent pegs were driven in, and the cords tightened. The lamp was then lit and fixed to the tent pole, and the boys set

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about preparing their supper and making their beds.

Bill had camped-out before, but everything was new to Ronald, and he felt a delicious thrill of excitement at the thought of camping on those grand old hills. He went out to look about him before turning in for the night.

The clouds which had gathered round the hill-tops at sunset, like the feathers of a great mother-bird, bending over the cradle to say good-night to her babies, had all disappeared. The sky was intensely clear and the air had a touch of frost in it. There was no moon, and Ronald felt awed into silence at the immense darkness and stillness and loneliness. The mountains walled him in on every side—their bare cliffs and jagged rocks appearing to stretch right up into the heavens, and some of the stars seemed to have come down to rest on their brows, and look at the stranger who had intruded into their domain.

Ronald had never seen such stars before. The sky in London had looked to him like the ceiling of a great hall with the stars fastened to it; but here there was no end to the distance he could see, and the stars were not fastened to anything. He realised that they actually were worlds in space, and remembered that our earth was also a star. As he gazed at a bright planet resting just above

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the pinnacle of rock at the top of the valley, he wondered whether there might be any mountains in that star, and another boy, gazing into his sky, wondering in his turn whether or not our earth were inhabited?

Bill had lit the fire in front of the tent, and Ronald was glad to enjoy its warmth for a while, before he rolled himself up in his blankets for the night. Although at first he could not keep his eyes from the glare of the fire which shone through the canvas, he was soon fast asleep. He remembered nothing more until he felt a cold blast of air coming in upon him, and heard Bill saying: "Ronald, we have no salt or sugar. You must go down to the shepherd's house and borrow some, while I light the fire."

Breakfast over, the boys started prospecting on their own account, while they waited for old Willie, who was to join them presently. With keen eyes they examined the banks of the brook, and at every likely place a basin-ful of soil was taken and washed. Several times they thought they saw the glimmer of the yellow gold, but it always eluded them.

"A fine lot of work you have done," shouted old Willie, when he arrived. "I thought you were to have all the turf and peats taken off the place I showed you yesterday."

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The boys explained what they had been doing, but the old miner told them that although it was quite possible they might come across a nugget; if they wanted to make sure of having some gold to take home with them, they must work systematically.

A dam was built across the burn near the place where old Willie thought they should take the gravel from. The long trough for catching the grains of gold, about a foot wide with sides four inches high, was placed in position at the edge of the stream. A broad trough for washing the gravel in; with an iron grating in the bottom, was laid across the gold catching trough, and a third was used to lead the water from the dam to the washing trough.

When the earth and peat which covered the gold-bearing gravel had all been removed, Ronald filled the barrow with gravel, wheeled it along a plank down the bank, and emptied it into the washing trough.

Old Willie raised the sluice to allow a small stream of water to flow on to the gravel, and raked the stones backward and forward until he was sure that any particles of gold that might have been sticking to them had been washed off into the long trough beneath.

After five or six barrow-fuls of grey stones had

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been washed in the trough, old Willie shut off the water till there was just a trickle, and began to stir up the mud at the bottom of the long trough very carefully, while the two boys, on their hands and knees, watched the muddy water gliding down.

At last Ronald spied a yellow glint. "Yes," said old Willie. "There it is. Pick it up with your finger nail, and put it into this bottle."

A small round medicine bottle was filled with water, and Ronald added his grain of gold along with two or three other specks that had been found by old Willie. Then, having corked it carefully, he held the bottle against his coat sleeve and gazed at the gold in the sunlight.

The gold fever had fairly caught the young miners now, and after a light dinner and a short rest, they were hard at work again, cutting a passage about six feet wide into the side of the bank. They had proved that there was gold in it, so they determined to remove the upper soils and systematically scrape up and wash all the gravel lying on the top of the rock.

Ronald loosened the earth with a pick-axe, while Bill shovelled it into the barrow, wheeled it down the bank, and emptied it at the side of the trough. Presently his pick struck something more solid than the soil, and after digging round

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it he discovered the trunk of a tree embedded in the peat. The wood was quite black, and very hard. Ronald wondered why it had not turned into coal, but old Willie explained that it had not been buried nearly long enough for that, although it had probably been there for many hundred years.

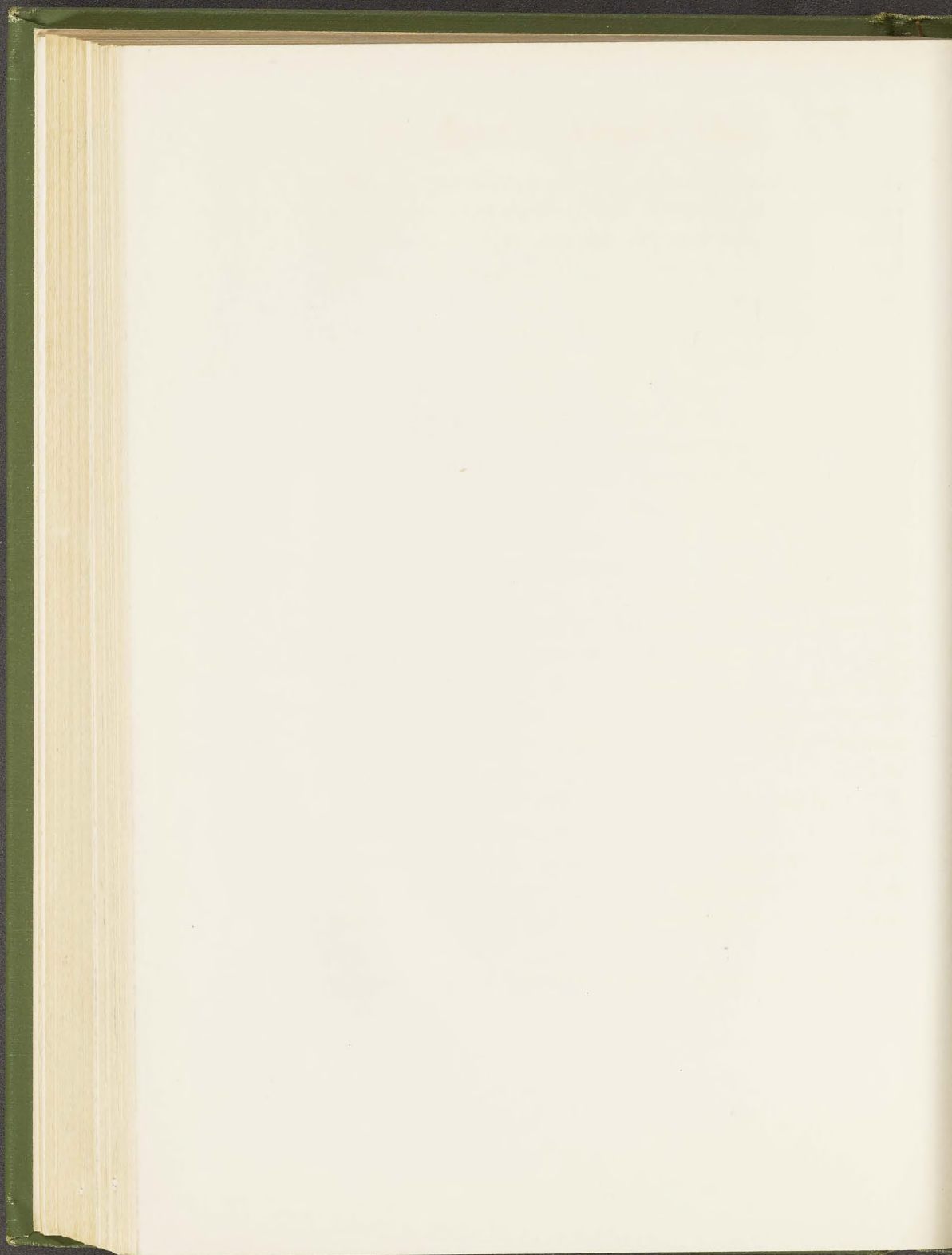
"Peat has a wonderful property of preserving anything that is buried in it," he said. "In Ireland bog oak is dug out of the peat moss, and used for many purposes."

At last the peat, soil, gravel, greyish gravel, and coarse stones had all been removed. The grey stones and the dust scraped off the top of the solid rock were carefully placed in the barrow, wheeled down to the trough and washed. They found five small particles of gold in one barrowful of gravel, which had come from the left hand corner of the "claim;" so they scraped out another barrowful from the top of the rock at that corner, and washed again, when they found three grains more. Old Willie told them that miners often discovered what they call a "pocket"—a hole in the rock in the bed of the original river, into which the gold had been washed, and that in Australia thousands of pounds' worth of gold had been found in such pockets.

Old Willie was carefully raking the gravel



Washing the Gravel for Gold
Stephen Reid



The Bill-Ronald Company

backward and forward in the washing trough, while Ronald and Bill were down on their knees beside the long trough keenly watching all the little bits of rock and gravel that were running down in the water.

"There's a nugget," cried Ronald, as he made a dab at the trough with his finger.

"Where?" shouted Bill. But it was gone.

"I'm certain I saw a bit of gold running down the trough," said Ronald.

"All right," said old Willie, as he shut off the water; "now we'll look for it."

"Don't touch the trough, boys; wait till the water runs itself clear; then look carefully at the bottom of the trough."

There was no sign of a nugget. One by one the ridges of wood placed across the trough were removed and the small deposit of sand and mud in each compartment was carefully stirred up and washed away, but there was no sign of Ronald's nugget.

"I'm afraid you're mistaken this time," said old Willie, as he removed the last bar of wood from the trough. "There it is," shouted Ronald, as he nearly tumbled into the trough in his eagerness to seize the glittering speck that he saw again in the water.

"It's gone again, but I'm certain I saw it."

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"There it is!" and this time he caught it and held it in triumph between his finger and thumb.

It was a little splinter of white stone covered on one side with gold.

"Oh! that explains why we so nearly lost it," said the old miner. "Our system of catching the gold in the trough depends on its being so much heavier than anything else. Gold is seven times heavier, bulk for bulk, than the gravel and stones amongst which it is found, so we can let the water wash them away, without fear of its carrying away the gold too. But there is so much rock in this piece, compared to its amount of gold, that it was all washed away together.

"You should keep that bit carefully, Ronald, as it proves conclusively that all these grains of gold have come out of a gold quartz vein; for there you have a piece of the actual quartz with the gold on it."

"I will have it made into a little brooch," said Ronald, "and send it to my mother."

"Yes, it would do very nicely for that," said Willie.

The boys had worked as they listened and talked. Instead of cutting down from the surface, they presently began to scrape out the gravel which lay on the top of the solid rock until they formed a cave. In their eagerness to get the gold they

The Bill-Roland Company

forgot that there was nothing to support the mass of earth hanging above them, and down it came. Ronald was buried beneath it.

Old Willie and Bill were soon to the rescue, and he was dragged out none the worse; but he had had quite enough of gold mining for that day.

Bill brought him the medicine bottle with the shining gold at the bottom to cheer him up. As the result of the day's work they had found as many grains of gold as would cover a threepenny piece.

Old Willie preferred to go home to spending the night with them; so the boys accompanied him to the brow of the hill, and said "Good-night."

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A CARBONIFEROUS FOREST.

The abundant vegetation of the Carboniferous Period which now forms our coal seams, consisted mainly of gigantic tropical plants, which were not highly organised enough to be called trees. There was no cold winter, and the surface of the whole of our planet was



a warm swamp teeming with vegetable life growing in the mud, floating in the water and hanging in the air. It was the coming of periodic winters that compelled the soft juicy plants to change their structure to resist the cold, and to store up nourishment, and finally evolve themselves into our present trees.

Chapter the Tenth

The very beginning of a Lead Pencil



HAVE you ever thought of asking the geological history of the fire we are now warming our toes at, Ronald?" asked the doctor.

"We see an iron grate, polished with black lead, coals burning in the grate, and a brick of fire-clay at the back of the fire to prevent it burning away the iron. What can the Geologist tell us about the history of these substances?

"The black lead that the grate is polished with is not lead at all. It is not even a metal like iron or tin, but it is really a form of coal which has been so changed by the action of intense heat that it will not burn at all. Indeed, it is used for making crucibles for melting other things in, and can be made to resist heats that would melt even fire-clay.

"In an ordinary lead pencil most people would say we had two things—the black lead that marks the paper, and the wood in which it is inserted.

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You all know that the lead pencil has been made in some factory, but have you ever thought that the "black lead" is a vegetable product, and is as much the remains of a living plant as the wood of the pencil? Shall we try to begin at the very beginning of a lead pencil? The plumbago or graphite, which is the proper name for the black stuff you write with, and use for polishing grates and kettles, and put into the working parts of your bicycle to make it run smoothly, was originally a gas which chemists call carbon di-oxide. It is formed by combining two parts of oxygen with one of carbon.

"We are all busy manufacturing this gas in our bodies, and breathing it out into the air of the room. The fire in the grate there is turning the coal into this same gas, and sending it up the chimney. Very early in the history of the world there was this carbonic acid gas. It probably came out of the sun along with the rest of the material that the earth was made of.

"Thousands and thousands of years after the stuff that the earth was made of came out of the sun, and had been flying through space round and round the sun, life first appeared on the earth.

"You know what life is, but you cannot tell me what it is. Thousands of the cleverest men have been trying for over a hundred years to find out

Beginning of a Lead Pencil

how life first came into this world ; but they have not been able to tell us.

“All that even the cleverest men can say is, that plant life is a thing, or a power, which in the presence of moisture and under the influence of sunlight, can take carbonic acid gas and water out of the air, and break them into carbon and oxygen and hydrogen ; and then build the particles of carbon and hydrogen up into a new substance which is alive. Everything which is alive, begins, grows and dies. Scientists can tell us a great deal about *how* it begins, grows, and dies, but no one has ever told us *why*.

“We are all so accustomed to seeing plants and trees growing in the ground, that we think that all the food for the plant comes from the ground. As a matter of fact, however, only one-fiftieth part of the substance of a plant consists of mineral matter taken from the ground, the other forty-nine-fiftieths of the plant consist of carbon, nitrogen, and water taken from the air. The roots of a plant need air as well as the leaves, and a land plant will die from drowning, if the ground is so soaked with water that its roots cannot get air.

“The earliest form of plant life was probably some kind of one-celled plant like yeast growing in shallow water ; but scientists have not yet determined whether we should call it a plant or a colony

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of small animals living together. When we get down to the very lowest forms of life it is difficult to say whether they are plants or animals. We shall be going far enough back, if we begin with the yellowish-green spots called lichens, which we sometimes see on rocks that have been long exposed

to the sun and rain. They are among the simplest forms of plant life. Lichens grow very slowly, and even though you look at them through a powerful magnifying glass, you would hardly see anything but a few specks of colour. Every plant that we know, has roots and leaves, but these lichens have neither.

The lowest and simplest living things are small specks of jelly which we call cells. They have the power of taking in food from the air. The cell which is originally

Stages in
develop-
ment and
multipli-
cation of
cells

round, gradually becomes egg-shaped, and then thickens at each end till it is like a dumb-bell, then this dumb-bell breaks across the handle, and each end of the dumb-bell becomes a separate cell and begins to grow, and then becomes egg-shaped, and then dumbbell-shaped, and then breaks across the handle, and so multiplies itself.

A lichen is really a partnership or colony of separate cells living and working together. It is

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an organised community, and is in some ways pretty far up in the scale of life; but we needn't go into that just now.

"At the time when the coal was formed, the world was a very different place from what it is to-day. There was a great deal more of carbonic acid gas in the air than there is now. Carbonic acid gas, although it feeds plants, poisons all the other living things. If I were to go round this room and shut the door and windows, and seal up all the cracks round the window sashes, and block up the chimney, so that no air could come in or out, we should soon begin to feel very sleepy. Then we should all have headaches, and possibly we should fall into a sleep from which we should never awake, because we would be poisoned by the gas which we are all breathing forth out of our bodies.

"Some people say that in the carboniferous period, the earth was one great warm steaming greenhouse. We now find the remains of tropical vegetation all over the world, even at the North and South Poles. It was the age of perpetual heat, mist, and fog. The whole land was soaking with water. Steam was rising up into the air and being condensed into clouds, and coming down again in the form of rain. Wide areas of land were covered over by shallow lakes and

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swamps connected by narrow channels. The action of winds and tides, and the rotation of the earth kept warm water always circulating over the surface of the globe, and (like the hot pipes below the flags of the greenhouse) continually giving out moist heat. The clouds which surrounded the whole world, like a great pile of blankets, twenty miles high, kept the heat from escaping into space, and at the same time stored up all the heat that came from the sun. If you went into a hot greenhouse you would soon become tired, and if you were imprisoned in such a place, you would get very ill and weak and white-faced, and probably die.

You know that in swampy places plants grow very quickly, and are all soft and juicy and flabby. You might almost say they are just so much water made to stand upright, and coloured green. Nowadays, the winter comes every year and kills off all these soft flabby plants, but in the coal age there was no winter, and all the plants grew big and fat and died very quickly of over-eating. In this way huge masses of vegetable matter soon covered the whole country. All this time in the world's history the surface of the earth was constantly sinking. A land on which some great forest thousands of miles across, was growing, would gradually sink down lower

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and lower, until the rivers all round it, would turn and flow into it, instead of into the sea, because it would be lower than the old sea bottom; and perhaps the sea itself would flow up along some sunken river valley, and cover a whole forest.

"This would kill all the trees and plants, and they would fall down and form a tangled mass at the bottom of the water.

"You remember watching Jack as he tried to make baby's ball, which 'Spot' had bitten, stand up all right, and you noticed how, when one part was pushed in another part came up. The earth at this time was probably in the same condition, and when the land carrying this great mass of vegetation sunk; somewhere near by, other parts of the earth's surface would rise up.

The rain in those days was probably one hundred times heavier than it is now, coming down in thunder showers every half-hour, and washing away the sides of the mountains very quickly. The rivers would be thick with mud and at times flow like treacle, bringing down sand and gravel enough to fill up the great lake in which the old forest of marsh plants had been drowned. Floating masses of vegetation often became water-logged and sank to the bottom.

"Now, as the whole world was a steaming,

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stifling hot-house, all kinds of plants grew very quickly. Long before the lake had been filled up, giant horse-tails, mosses and jungle plants, would creep in from its shores, and all kinds of water weeds would be growing on the surface. Then as the lake became shallower and shallower, scale-trees and monkey-puzzle trees and tropical ferns would spring up out of the marsh, and their dead stalks and leaves would help to fill up the lake, until a new forest had grown on top of the old one. This great heap of mud and sand and growing trees, piled up on the subsiding crust of the world, would make it very much heavier, and help the land to sink down into the earth again, and make a new hollow, which would fill with water. This would kill the trees, and they would fall as a tangled mass to the bottom, and so repeat the story.

“Coal is bottled sunshine. The sunbeams gave the growing plants their strength and energy to break up the little particles of carbonic acid gas, digest the carbon, and build it into their own bodies, and set the oxygen free. This store of carbon supplies our coal to-day, and when we put the coal in the fire, we are reversing the work done for us by the plant cells.

“When the coal burns, its carbon is united again with oxygen, and forms carbonic acid gas that flies away up the chimney, while some of the

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heat comes out into the room and warms us. As we sit now, warming ourselves by the fire, we are really enjoying the sunshine of millions of years ago, preserved for us by little green plant cells that lived and died in that far-away past.

"But," asked Ronald, "if during the coal age, the whole world was a big greenhouse, so filled with growing plants that you could not walk through it anywhere without crushing them down, and squeezing your way in between tree trunks, how is it that we do not find coal everywhere?"

"Well," said the doctor, "there was plenty of vegetation that might become coal, but there was no bottle. While the plant is growing, it is taking carbon out of the air and building it up into itself. When the plant dies, thousands and thousands of 'Breakers-up' cluster all round it, and they break up all its particles into carbonic acid gas. All the substance of the plant that came out of the air, goes back into the air, and the mineral salts which the roots took out of the ground are left lying on the ground. The same thing is done very much more quickly when we set fire to a pile of sticks. This is why we find that in places where we know forests have been growing for over a thousand years, there are only a few inches of vegetable matter lying on the ground.

"I think I saw you this morning helping Lizzie

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to bottle some cherries. You saw that the cherries were placed in bottles, and water was poured in to fill up the spaces between the cherries. Then the bottles of cherries were put into a large pan and heated till the water boiled, in order to drive out all the air. A special lid with india-rubber lining was screwed down over each bottle, so as to prevent the air from getting in again. In this way, the 'Breakers-up' were prevented from attacking the cherries, and they will keep good, and may be eaten two or three years after this.

"Our coal has been preserved for us in the same way as the cherries or the tinned meats which we get from America and Australia.

"If a tree falls on the ground and dies, nearly all its substance is broken up into gases and escapes into the air; but if it falls into water, the water preserves it, and it may last for hundreds of years. The first preservative agency which made our coal was the water, into which the tree trunks fell. We always find in a coal field that above the coal there is a layer of some kind of clay or mud rock. It is not always directly on top of the coal, there may be one or two layers of sandstone between. This layer of clay stuff, which is called shale, or blaes, acts in the same way as the lid of the jar in which you saw the cherries preserved this morning. It seals up the moist mixture of fallen trees and mud, and

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prevents the carbonic acid gas, formed by the decomposition of vegetable matter, from escaping. By thus bottling the whole thing down, it keeps the fallen trees from decomposing, until by the action of the weight of other rocks piled on top of them and the heat coming up from the centre of the earth, the tree trunks are squeezed and baked and boiled into coal.

“It is only when all these agencies combine that we get coal. First of all we have the vegetation consisting of marsh plants, tree ferns, tall trees, and general tropical jungle. Then we have the water, which causes the trees and plants to fall, and covers and preserves them from further decomposition, until the beds of mud and sand have been laid down on top of them. Then the layers of clay and shale cover all, and finally they become coal.

“If the gases formed by the rotting of this vegetation had been allowed to escape into the air, we should have no coal. It is these gases imprisoned in the ground for millions of years, that poison the miners and cause explosions in the pits to-day. Currents of fresh air have to be constantly forced down into the mines to drive away these gases, which exude from the coal when the seams are opened up.

“Very frequently we find the roots of the coal plants and trees growing in a layer of clay or

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sandstone; then we have a seam of coal formed from the remains of this vegetation resting directly on the stumps of the old trees. Above these, we find a bed of sandstone, then another of shale or blaes, and after this, in a higher bed of clay, we find the roots of the trees of another generation of forests with a layer of coal on top of them, and so on till in some places as many as fifty seams of coal have been found lying above one another and all sandwiched in between sheets of sandstone and clay.

“You must remember that while by far the greatest part of our coal is formed of the remains of marsh plants, and not of trees at all, still during the carboniferous period there were a number of trees growing on the uplands which surrounded the swamps. Occasionally one of these trees would be swept down by a river into the swamp, along with the coal-forming plants, and so preserved unto this day.

“You will be wondering when I am to come back to the lead pencil. Well, plumbago or black-lead is a very much rarer mineral than coal, and is found where the coal has been baked by an intrusive mass of molten rock squeezed in above or below the seams of coal. There are several coal fields where ordinary coal is found over a large area, but when we come across a solid plug

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of lava which has cooled and filled up the pipe through which it poured, we find that the coal nearest the plug has all been burned to coke. The coal next the coke has been melted by the intense heat and changed from coal into plumbago. The coal lying near it again, having in some places been changed by the heat of the lava into anthracite, or steam coal, which is so much used by our warships. It burns without any smoke, because the gases in ordinary coal, which give rise to smoke, were all burnt out of the steam coal by the lava, which baked it underground thousands of years ago.

“There is a vein of plumbago or blacklead in the level which the company’s men are driving into the back of the hill this side of the Windgate. The rocks it is found in are full of fossil ‘sea pens’ or graptolites, showing that they are far older than the Coal Measures, as we call the rocks the coal is found in. It is, however, pretty certain that most of the black lead we know of once formed part of a growing plant.”

Chapter the Eleventh

The Carboniferous Period

When every plant and animal was big and lazy, and grew fatter and fatter until they died of over-eating.



WE were talking last night about the wonderful history of a lead pencil. We saw that the 'black lead' was as much a vegetable product as the wood it was encased in, and we thought of some of the great changes that had taken place during the hundreds of thousands of years that had passed, after the plant that formed the 'black lead' died, and before the cedar tree that supplied the wood was born.

"We saw that the state the world was in during the coal age or carboniferous period was very favourable for the growth of rank luxuriant vegetable life of all kinds. Ferns grew into great trees, one of which would have completely filled this room. The graceful feathery stag-horn moss, which Ronald and Lizzie tracked down in its

The Carboniferous Period

ramblings among the roots of the heather on the hills this morning, and whose long, dainty, bright-green, velvet-coloured wiry tendrils, formed such a beautiful decoration for the dinner-table to-night, is the tiny grandchild of the giant Lycopods, which straggled all over the swampy world with stems as thick as your body and sent up tree-like branches fifty feet high. The horse-tails (*Equisitum* is their botanical name, from the Latin *equus*, a horse) grew into gigantic forest trees twice as high as this house, and all the air space between their branches was roped across and across with creeping plants, which climbed up, and hung down in long festoons, and twined round and encircled everything.

"All was big and fat and juicy and lazy and stupid.

"The plants were of a very low form of life and of very primitive structure. Hardly any of them had flowers. In



Club or Stag-horn Moss.

Secrets of the Hills

some it was difficult to distinguish between leaves and branches and stem, or to say whether any particular part was a leaf or a branch.

"Though gigantic tree-like plants clothed the world, none of them were as highly organised as our present trees. The highest forms of animal life were great fat newt-like creatures with little brains, but with both gills and lungs so that they could breathe both air and water. Insects flew about the tops of the trees, but the air near the ground was so full of moist vapours and the smells of decaying vegetation, that proper air-breathing animals could not live there even had they existed.

"The next time you see a horse-tail growing, pull it up and have a good look at it.

"It is the oldest, simplest, and loneliest living thing in the whole world. You will find it in every country from Britain right across Europe and Asia to Japan, from Japan to California, right across America to Greenland and Iceland, and back to Britain again. From the North Pole to the Equator, and from Timbuctoo to the Antarctic, the *Equisetum* is always at home, and ready to meet you. Away far back in very old rocks we find the fossil remains of horse-tails. Through the long succeeding geological ages, it contrived to live, and if you go out into the garden now, and look at any bit of ground that has been

The Carboniferous Period

left untenanted by cultivated plants, the horse-tail will have been one of the first weeds to come and grow there.

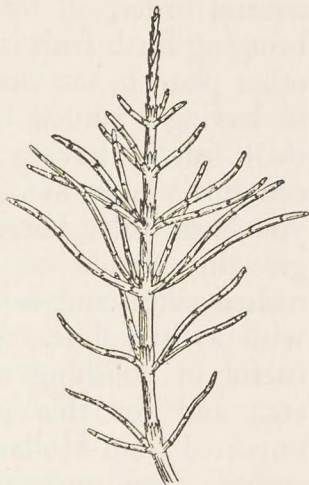
“It is the simplest plant to draw, because all its stems are straight ; it has no leaves and no flowers. Yet it has a beauty all its own. The beauty of absolute simplicity.

“One straight line down the page, that is its main stem. Then a ring of straight branches growing out on all sides of the centre.

“Another ring of branches springing out of a knot, or joint, in the main stem a little higher up—each ring of branches becoming slightly shorter, as the plant gracefully tapers to the top. Try

to break it, and it comes apart at a joint, each part perfectly symmetrical. It is so simple ; it is always beautiful and you cannot destroy its symmetry.

“The horse-tail is the loneliest living thing in the whole world because it has no relations. Every other plant and animal and bird and fish has cousins that are very like it, and are only just



Horsetail.

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distinguished from it by one or two points of difference.

“The *Equi-se-tace-ae* (to give them their proper botanical name, because they are very, very select) are not only a separate family, but a separate natural order, all by themselves. Their way of bringing forth fruit is different from that of every other plant in the world. They resemble animals in having a jointed backbone, and they resemble shell fish in having a hard outside skin, which contains a large amount of the mineral silica. If you burn a dry horse-tail in a gas flame you will get tiny beads of glass. Glass is principally melted silica, and is made by heating sand along with a little lime. This silica makes them very useful in polishing marble, ivory, cabinet-work, etc., and for this purpose large quantities are imported from Holland under the name of Dutch rushes. Seen under the microscope the fruit of the *Equisetaceae*——”

Here Ronald thought they were being let in for a botanical lecture. He had a horror of Botany, and thought all Botanists were dry-as-dust people who cut plants to pieces, and barked Latin names. They saw nothing in the most beautiful flower but complicated and uninteresting machinery for making seeds, which they always began to explain at such tremendous

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length that everybody was glad to escape from them.

"But, doctor," he interrupted——

"Well, perhaps, I was wandering rather far, Ronald, but when I see a horse-tail, I always think of it as a visitor from a strange world. A world which, it is quite true, existed on this same planet, which we call earth, millions of years ago, but where all the conditions of life were so different from ours, that we can hardly conceive them."

"But, doctor," said Ronald, "I can't understand how it could ever be possible for tropical vegetation to grow at the North Pole, and the whole world to be a steaming hot-house all the year round, as you said it was in the carboniferous period. Where was the heat to come from? If it came up out of the ground it would burn up all the roots of the plants."

"It seems to me," said the doctor, "very likely that the world hot-house of the carboniferous period was heated much in the same way that our hot-houses are heated to-day, by currents of hot water. The hot water currents were not enclosed in iron pipes, because the world had a mechanism of its own for making the water circulate, but the principles involved were just the same."

"The fact that there was no cover over the hot water currents was rather an advantage to the

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vegetation, as the escaping steam supplied abundant quantities of moisture, and it made no difference to the hot water system that the water pipe was five miles across instead of five inches—or even fifty miles. At the time the coal beds were made there were no great land continents and no oceans. The whole world was dimpled over with large islands and shallow seas. The crust of the earth was very much thinner, and like the wrinkled wobbly skin of a half-filled balloon. The warm currents of water coursed freely and regularly, from the Equator up round the Poles and back again.

“It is difficult to imagine Greenland enjoying the luxury of a hot climate, but fossil fig trees, and palms, and many other tropical plants, have been discovered in the rocks there, so that we know these trees must have flourished in Greenland at one time. There is also ample evidence to prove that the country round the South Pole once supported a tropical vegetation.

“I cannot explain how such a great change has been brought about, but if you think for a little about some of the effects which the warm currents in the ocean and in the air produce at the present day, you will be bound to admit that even greater changes in the climate of any part of the world are not impossible.

“The Gulf Stream, or as it is now called the——”

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"Oh, yes, I know all about the Gulf Stream," broke in Ronald; "I've just been reading a story about it."

"If it were not for the Gulf Stream our winters in Scotland would be a great deal colder. The Shetland Islands, though within five degrees of the Arctic Circle, enjoy winters as warm as some places on the Mediterranean. The cold currents on the north-east coast of Asia, on the other hand, make the winters terribly severe. Venice is actually in the same latitude as Vladivostock, the Russian Naval base in the war with Japan, where so many of their soldiers were frozen to death.

"Without the Gulf Stream, Stornoway would be as cold as Klondyke, where the gold miners hack out the frozen gravel, and store it in heaps, and wait for the summer to come and thaw the rivers, before they can wash the gold out of it.

"North and South America are very nearly two separate islands, and are only connected by a long narrow strip of land. Now suppose that any part of this narrow strip were to be cut through, or to sink below the level of the sea, so that there was a free passage from the Atlantic to the Pacific Ocean, the Gulf Stream might change its direction altogether and flow into the Pacific and up the west coast of North America. The

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north-west of Canada would then feel its beneficial effects and have warmer winters than ours. The glaciers would disappear from Alaska. Klondyke would be no longer frozen. The Bhering Straits might become a pleasure ground. But what would become of us? Glaciers might again creep down and cover Scotland and the whole of the north-west of Europe."

Here Bill looked up from perusing the pages of the "Up-to-date Scout." He was so used to hearing his father explaining geology to everybody who came to the house, that he rarely paid any attention to him. He was deep in the middle of a thrilling story of a great battle between the people of Britain and a gigantic fleet of war airships which had been sent over by some Irish Fenian American millionaires to wipe England off the face of the earth.

"I tell you, wouldn't it be a much cleverer thing if the Fenian millionaires, instead of building airships to cross the Atlantic and blow up the whole country by dropping explosive bombs down on top of us, were to cut a great canal, and turn the Gulf Stream into the Pacific Ocean, and so freeze us all to death and then make London a game preserve to come and hunt polar bears in?"

"Besides, it would pay, too," added Ronald,

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who was struck by a new idea. "If they thawed out the Yukon district they would get all the gold, and if they made the whole of the north-west of Canada a warm country, think how valuable all the land would be. Then if warm currents instead of Arctic currents flowed round the coast of Greenland——"

"But," said the doctor, "what would become of 'Poor Old Oireland'?"

"I forgot about that," said Bill, "but I suppose they would send their airships and take away all the Irish people first and give them farms in the new warm Greenland."

"Just imagine," said Ronald, "when the Fenian Americans had their great canal made, they could stand by the sluices and control the climate of the whole world, and threaten everybody, that they would either freeze them to death, or stew them alive by altering their climates, unless they gave the Americans everything they wanted."

"That is all very interesting, boys," said the doctor, "and it shows you understand that there are a great many other causes which determine the climate of a country besides its position,—north or south of the Equator; but I am afraid we must say good-bye to our old friend the Gulf Stream. It has been killed by a thermometer, and is already referred to by geographers as a myth. Where

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the Gulf Stream could not be traced on the surface of the ocean it was supposed to have dived underneath the colder water, and to be flowing along at a greater depth; but registering thermometers have been let down, and the whole of the sea has been thoroughly tested without discovering any signs of a Gulf Stream.

“Geographers now call the body of warm water which flows round the north-west of Europe the “South-West Drift,” or “Anti-Trades Current,” and account for it by the prevailing winds in the Atlantic Ocean and the rotation of the earth. They have made a large model of the Atlantic basin, and have proved that all the currents that we know to exist, can be accounted for by the action of the prevailing winds.

“We shall come back to this subject when we try to understand how the ice sheets once covered the whole of this country, and why they have disappeared.”

Chapter the Twelfth

The Secret of the Hills



STANDING beside the burn in the depths of the Glen, and looking up at the hills around us rising into the sky, as if to shut us in from all the rest of the world, I am not surprised that you refuse to believe that millions and millions of tons of solid rock once filled up the entire space between the hill tops on either side of us ; and that all this enormous mass has been carried into the sea by the tiny stream at our feet." (See view of "the Windgates," page 104.)

"I cannot believe it at all," said Ronald ; "it seems to me quite impossible."

"I am not surprised to hear you say that," said the doctor, "and as long as you stay down in the valleys, I needn't argue with you, for I should never convince you. But if you will come with me to the top of the hill there, you will realise that the dozens of hill tops you see standing around

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you, are all part of the one tableland, which has been cut across and across by river valleys, until it looks like a collection of separate hills.

“You read in the geography books that a mountain is a hill over one thousand feet high, and if you said a hill was a small mountain, few people would say you were wrong.

“In geology, however, we do not distinguish between the hills and mountains in regard to their size, but in regard to the way they have come into existence.

“Hills are the last remains of an elevated plain left standing by the rivers, which have gone on cutting valleys out of it until they have carried it nearly all away into the sea. The valleys were at first mere scratches on the top of the tableland. Year by year the rivers carved their way deeper into the land. The sides of the valley slipped down into the stream, and the force of the water carried this material right away to the sea.

“The river valleys were constantly growing deeper and broader, and cutting their way back into the tableland. The land between two valleys was eaten away on both sides, till from being a fast vanishing strip of country, it became a mere ridge between two great wide valleys. The very memory of the former tableland passed away, and men said the rivers rose out of the hills.

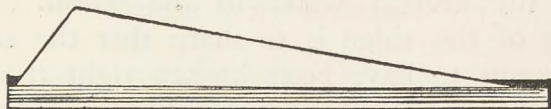
The Secret of the Hills

"But where did the elevated plains come from?" asked Ronald.

"The elevated plains were formed by movements of the earth's crust, which caused large parts of the surface to rise up from under the sea. If we liken the earth to a balloon, from which some of the gas has escaped, the high tablelands are the places where the loose skin of the earth has wobbled up out of the water.

"You will understand it better after I have explained to you the origin of the great earth foldings which we now call ranges of mountains straggling in long broken lines right across the surface of the world. The map of the Western Hemisphere shows quite plainly that the Rocky Mountains in North America and the Andes in South America are really one great ridge running down the west side of the continent for ten thousand miles.

"Take a sheet of paper, fold back the margin, and stand it on the table.



"Look at it endways and you have a good model of North and South America, with its steep slope down into the Pacific, and its gradual descent towards the Atlantic. Press it down with your

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finger in the middle of the ridge and the Atlantic Ocean will flow into the depression and form the Gulf of Mexico, dividing the two halves of the continent. The surface of the Western Hemisphere was folded upward in the same way as this page, and the great rivers of America have since scratched their channels out of it.

“The force that raised the immense ranges of the Andes and Rocky Mountains out of the bottom of the ocean right up into the air, was the force of the earth’s skin contracting in order to fit itself to its inside core, which had cooled and therefore grown smaller. This force of contraction pulled the west and the east sides of the continent towards each other, and elevated the mountain ridge; just as you could cause the ridge of the folded sheet of paper to rise higher from the table, by pushing the opposite sides of the paper together.

“The west side of South America is exceedingly steep, and goes rapidly down many miles into about the deepest water in the world. The folding of the ridge is so sharp that the earth’s crust seems to have been broken right through, and along this weak part we have a long line of lava out-flows and active volcanoes. Part of the coast of Chili is still rising out of the ocean. Earthquakes are of frequent occurrence. The one that destroyed San Francisco recently,

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was not remarkable for its intensity, but only because it happened to strike a large town, and consequently caused immense damage to life and property.

“In the Old World the crummings of the earth’s



Relief Sketch Map of Eurasia.

skin are more complicated. Your mountain ridge is now three-sided. Turn the paper with the folded side of the sheet towards you. Fold down the margins at the top and bottom as well, and stand the paper on its three upturned edges.

“You have now something like the continental

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block of the Old World, sloping gradually to the north, and with steep descents into the Atlantic in the west, the Indian Ocean in the south, and the Pacific in the east. This includes the slope down into the Atlantic and Indian Oceans, and regards Japan and the chain of islands to the north as the peaks of a submerged mountain range.

"The earth's skin is wrinkled into parallel semi-circular ridges, resembling the folds of festooned drapery. The relief sketch map of Eurasia shows that all the ranges of mountains are parts of one earth crumpling. A series of up-foldings sweep round the edges of the continent parallel with the boundary oceans in a general south-east, east, and north-east direction. Scotland is on the steep edge of Europe, and exceedingly volcanic. It was the great east to west up-folding, of which the Ural Mountains are the most prominent sign, that upset the balance of the Eurasian continent, turned some of the rivers out of their old courses, disjointed the mountain chains, and greatly complicated the crumpling of the Eastern Hemisphere."

"That all sounds beautifully simple, doctor, but how are you going to prove it?"

"Well, Ronald, how are you going to prove anything else? You have the map before you. You can't help seeing that all the mountains in

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the world are part of one system. All the ranges run into one another. None of them spring up at random."

"Yes! but that doesn't prove that the mountains have been made by folding."

"Nearly all the rocks in the world have been laid down in great flat layers, one above the other.

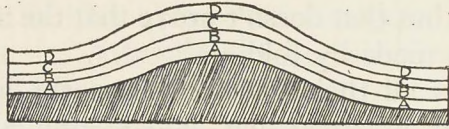
"The materials of which the successive layers are composed have been brought down by rivers and spread out over the floor of the ocean, and each layer was in its turn buried under the succeeding one. We can trace the same succession of rocks in the same order, stretching across the country for thousands of miles.

"When we come to the slope of the mountain, we find that the series of rocks we are following does not stop short, but continues right on, rising with the rise of the slope. On the top of the mountain we find our rocks *A*, *B*, *C*, and *D* are still lying under one another in the same order, and that the series continues unbroken down the opposite slope.

"It is quite clear, therefore, that these layers at one time were all lying flat one above another, and that they have been folded up together into a ridge, which we now call a range of mountains."

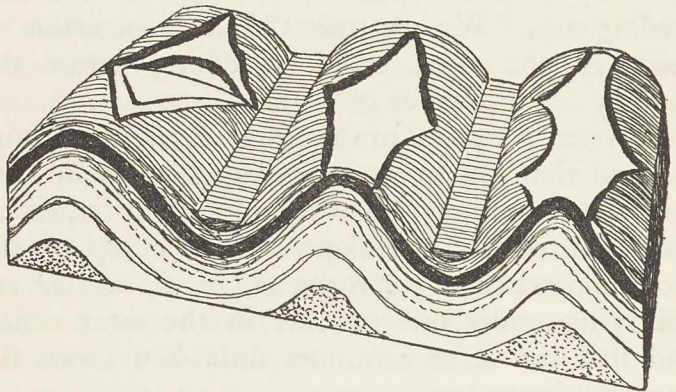
Secrets of the Hills

"I cannot understand that, doctor. You talk about folding up Europe and Asia as if they were



Mountain folding.

a sheet of newspaper. But there are many cubic miles of solid rocks in the Ural Mountains alone, and it would take an enormous force to shove the



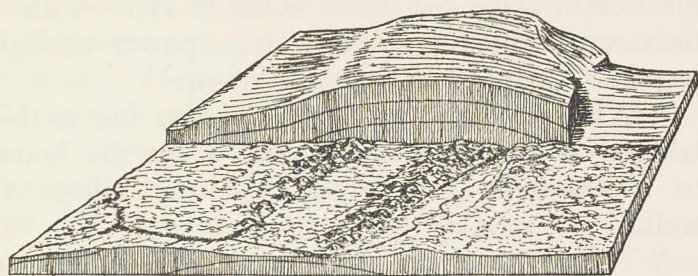
Jura Alps, showing folding of original strata, erosion of mountain tops, and filling up of valley by the products of erosion of mountain tops.

two sides of a continent towards one another, and to pile a range of mountains right up into the air."

"If you had a wet postage stamp lying on

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the table, Ronald, would it take an enormous force to move one end of the stamp towards the



The Unita fold in the background is supposed to have remained uneroded, while the foreground shows the Unita Mountains as they exist now.

other, sufficiently far to make the centre of the stamp rise above the table the hundredth part of an inch?"

"Well, no, doctor! not when you put it that

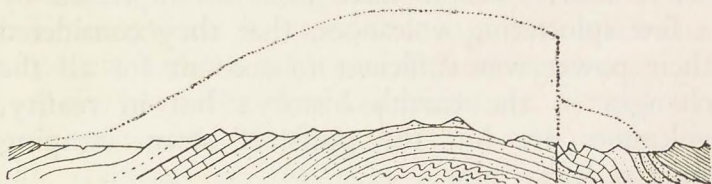


Diagram of the actual strata, by continuing the direction of which it was possible to construct the relief model of the Unita range up-folding shown above.

way. I suppose you are coming back to Mount Everest."

"I just want you to think a minute, Ronald,

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about the enormous power there is inside the earth. If this dining-table were an iron tank filled with water—a steam boiler in fact—with a furnace underneath, would it have power enough to make a crinkle in a postage stamp?”

“Why, doctor, if a steam boiler as big as this table were to explode, it would blow the house to smithereens, and wreck half the village as well.”

“The power of expanding steam, Ronald, is one of the weakest of Nature’s forces, that is why man has been able to catch a little of it, and tame it, and make it work for him. Suppose this table were a steam boiler, Ronald, and that it was shrinking, would it be very wonderful if little puffs of steam escaped here and there from the cracks? People have been so impressed by a few spluttering volcanoes, that they considered their power was sufficient to account for all the changes in the earth’s history; but in reality, volcanoes are but the puffs of steam escaping from a leaky pipe.

“The mountain ranges of the world have been produced by a grand, slow, silent movement of the earth’s crust. Have you ever noticed a large mill or warehouse, with a row of round iron plates on its sides? This probably means that the walls have begun to bulge outward, because the weight

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of the upper stories was too great for them to carry. If this bulging were allowed to go on, the whole building would collapse. An iron rod is therefore run through the building from wall to wall. A wall-plate and a screw-nut are put on at each end, and the iron rod is then heated till it expands, and projects several inches beyond the wall. The nuts are then screwed down the rod close against the wall, so that the rod cannot slip back through the wall-plate again. The iron rod is then allowed to cool and contract. The force of its contraction is so great and so gradual that it drags the whole of the bulging walls together until they become quite perpendicular again. If the contracting force of a two-inch rod is sufficient to drag together the walls of a four storey building, you can imagine what an enormous power is brought into action when the whole crust of the earth contracts owing to cooling.

“We have seen that mountains are formed by upheavals and crinklins of the earth’s crust—like wrinkles on the skin of an apple, so to speak, which has shrunk as it dried.

“If you draw your hand slowly but firmly along the tablecloth on the table, the cloth in front of your hand will wrinkle up into folds, because you have pressed one end of the cloth along towards the other.

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“The skin of the earth crinkles up into mountains for the same reason that the tablecloth crumples up, when you push part of it along, that is, because the outside skin (the cloth) is too big for the inside core (the table) it is resting on.

“You will get the same result whether you push on to the table top two inches of extra tablecloth or whether, while you keep the amount of cloth on the table top the same, you make the table two inches shorter.

“This is a telescope table, Ronald ; just take the handle and unscrew it two or three inches and then screw it together again, and watch how the tablecloth first stretches and then crinkles up when you bring the leaves together again.

“The skin of the earth has become too big for it, because the inside core has cooled and therefore grown smaller. The crust of the earth wrinkles up into mountains because the contracting core draws the two sides of a continent closer together.

“The piece of cloth on that part of the table is longer than the part of the table it is resting on ; it cannot all lie flat, so some of the cloth must crumple up.

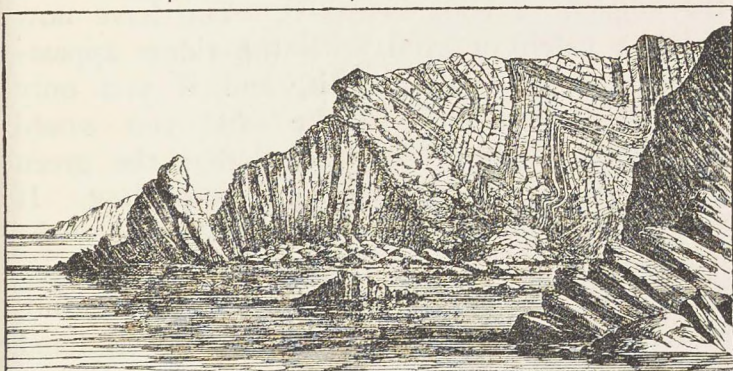
“The height of the wrinkles of the tablecloth is, of course, a hundred times greater in proportion than the height of the mountains above the sea level.

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"When we go to Dunbar, Ronald, I'll take you along to Burnmouth, and let you trace out the foldings of the rocks in the face of the cliffs there. The Silurian rocks rise out of the sea like a wall two or three hundred feet high, and as you row

D
↓

D
↓



Contorted Silurian strata half a mile north of Burnmouth, Berwickshire (Geological Survey). *D*, "dykes," formed by molten rock, which has been forced up from beneath into cracks in the overlying rocks caused by their being crumpled together.

along in a boat you can easily follow the foldings of the various layers throughout their whole length.

"It is quite easy to see how and why the wrinkles have been formed in the tablecloth, because it is lying open before you, and it is very

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evidently one continuous layer of green material, but the wrinkled rocks in the earth's crust are all covered up, and only appear in disconnected patches.

Pour some sand on to the wrinkled tablecloth till it is just deep enough to fill the hollows between the ridges, and level it by drawing the edge of a book across it. You have now a white patch of sand with the ridges appearing as green lines across it, and if you only looked at the surface of the sand you would have some difficulty in proving that the green lines were parts of one continuous sheet. If you scraped away the sand from the right hand side of a ridge you would find the green cloth sloping down or 'dipping' beneath the sand, and if you scraped it away from the left hand side of the next ridge you would find the cloth rising up from under the sand again, and you would be justified in assuming that there was one continuous layer of cloth stretching beneath the sand, and alternately rising to the surface and falling beneath it again.

"The layers of rock at the top of the ridges are said to form an 'anti-cline' (from two Greek words meaning *leaning against* one another), and the layers of rock at the bottom of the hollows are said to form a 'syn-cline' or to *lean in towards* one another.

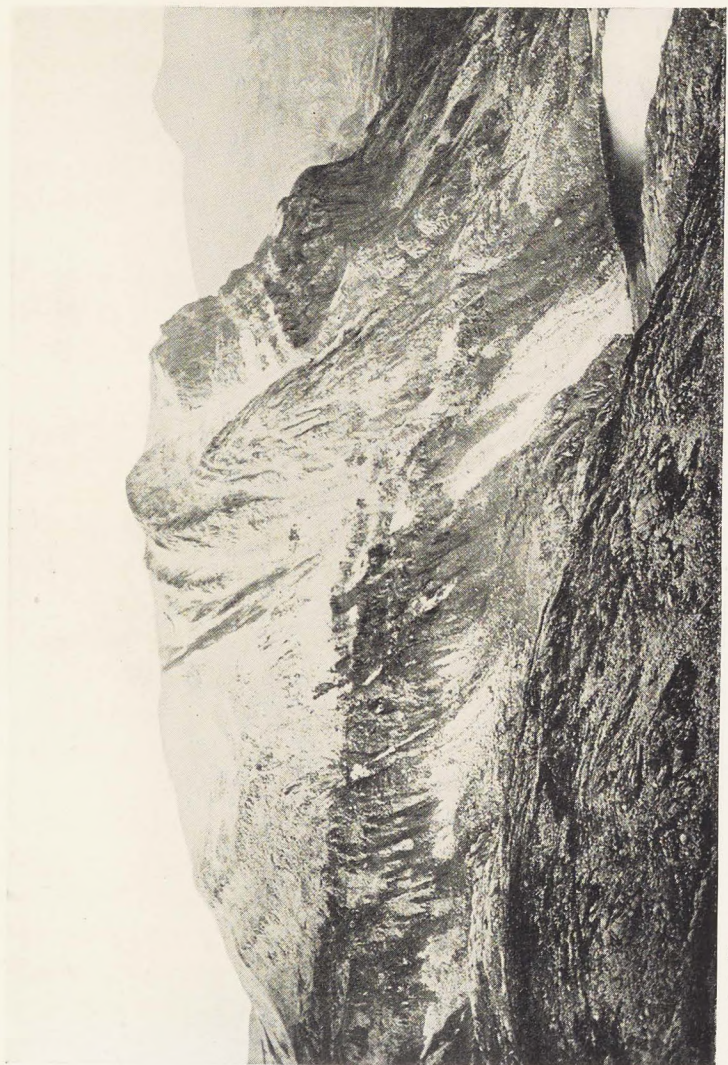


Photo Geological Survey

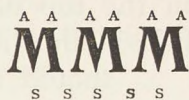
162

Na Tuan, one of the shoulders of Ben More, Sutherlandshire. Ben More has been actually lifted up into the air and toppled over, and is now standing on its head with its feet in the air. This is proved by the fact that all the strata of which it is composed are found in the reverse order. The newest limestones are at its base, and the old foundation gneiss covers the top of its back.



The Secret of the Hills

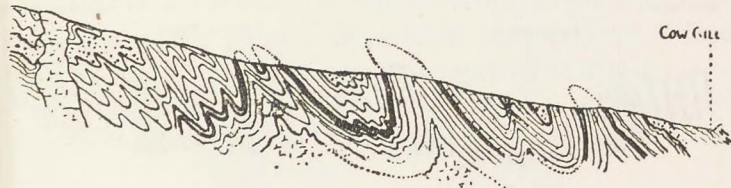
“If the foldings of a set of strata were represented by a line of Ms, the tops of the letters, *AAA*,



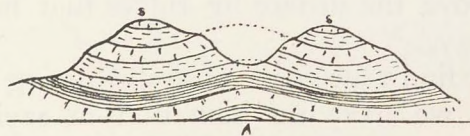
would be anti-clines, and the bottom points, *SSS*, would be syn-clines.

“We hardly ever find the rocks so sharply folded, and it would be more correct to say that an anti-cline was the top of a wave of rock, and that a syn-cline was the trough or hollow between two waves.

N.W.
OVERBURNS HILL



Section in Cow Gill, basin of Culter Water, Lanarkshire
(Geological Survey).



Hills eroded out of folded strata.
A, Anti-cline ; *SS*, Syn-clines.

Secrets of the Hills

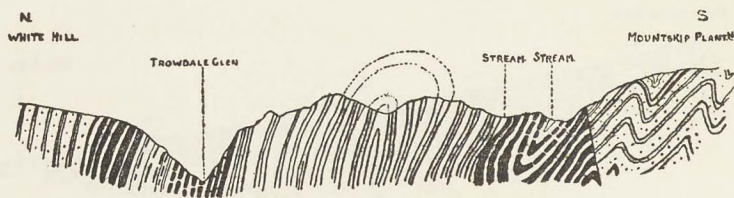
“Look again at the sand on the wrinkled tablecloth, and suppose we were to remove a layer half an inch thick from the top of it, cutting right through the folds of the cloth. Instead of ridges, we



Eroded Anti-cline.

should then find separate cut edges of the cloth at the surface of the sand. If

we scraped away a little of the sand from the edges of the cloth, we should find the angles at which they ‘dipped’ and rose, and after a little calculation we should be able to reconstruct the foldings and to say, ‘all these cut edges formed one continuous sheet, and were once



Section across Trowdale Glen, Water of Urr, Stewartry of Kirkcudbright (length, $\frac{1}{2}$ mile) (Geological Survey).

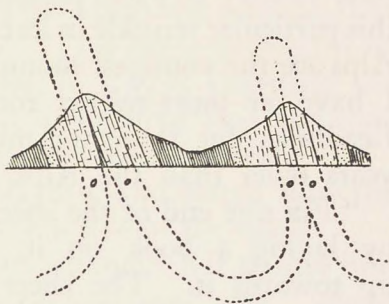
joined above the surface by ridges that have been worn away.’

“If we find a succession of strata dipping as in this diagram, we have no hesitation in saying that they formed part of an anticline, the top of which has been worn away, and whose height we could

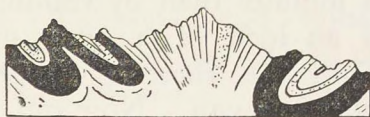
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determine by continuing the lines of the different strata until they met.

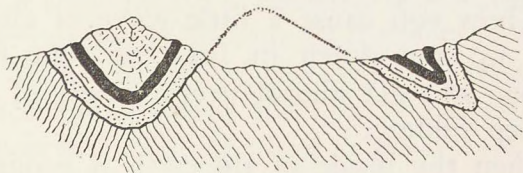
“By the same kind of calculations geologists can reconstruct the foldings of the rocks *o, o*, the tops of which have been completely removed hundreds of years ago, and also say how and where these strata are connected underground, as indicated by the dotted lines.



“Here is a section through Mont Blanc made by observing the angles at which the various strata dip below the surface and rise out of it again.



Section through Mont Blanc (“Fan Structure”).



Alpine structure.

“A series of these sections have enabled geologists

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to prove beyond all doubt not only that the Alps have been formed by a crumpling up of the surface of Europe in comparatively recent times, but to state exactly at what period in the earth's history this particular wrinkle in its crust was formed. The Alps are the youngest mountains in the world, and I have far more respect for these hills of ours in Leadhills, for they are millions and millions of years older than the Alps.

"Fix one end of the sheet of paper to the table by laying a book on it. Press the other end up towards it. The sheet will bulge up in the middle. That is a tableland.

"Just do it, Ronald! There is plenty of paper lying there, and you will learn more about mountain folding by working with a sheet of paper for ten minutes than by reading books for hours. Half an inch of a push up, is quite sufficient. Turn the sheet of paper with its raised edge towards you. Now run your finger very gently up and down the bulging paper. Notice how you cause a little wave of elevation to run up and down in front of your finger; and how you get almost every variety of gentle and steep folding.

"When the inside of the earth is cooling and contracting under its hard inelastic outer crust, the two opposite sides of a continent are being

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dragged closer together. This causes the surface to bulge up just like the sheet of paper. The slight pressure of your finger, which threw the bulge into all manner of waving folds, represents the weight of the rocks of which the bulging skin of the earth is built up. This immense weight of miles of overlying strata, is always throwing the crust downward, at the same time that the contracting earth is dragging its ends together.

“Bend a cigarette slightly and watch how the paper wrinkles up on the inside of the bend.

“Take the sheet of paper and roll it tightly into a solid rod (a mere hollow roll won't do).¹ Bend the two ends of the paper rod together. Never mind if some of the outside folds burst at the bend. Now straighten the rod and look at it. The layers of paper that were on the inside of the bend are all squeezed and crumpled together, while the outside layers are drawn out, and some of them are torn asunder.

“Unroll the paper and look at it. The extension and compression is repeated again and again. Each crumpling is the counterpart of the following one. The distortion of the layers gets less as you approach the centre of the rod, because the centre

¹ Tear the sheet of paper slantways down the middle so that one end is broader than the other. Let the broad end be inside the roll. Then hold it between your finger and thumb and tighten it up into a solid rod.

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layers were bent through a shorter distance than the outside ones.

“ Every part of the earth’s crust is made up of layers like the rod of paper. When any folding takes place the outside layers are stretched out and torn asunder, and the inside layers are all crushed together. The layers of rock which make up the earth’s crust are much more brittle than layers of paper.

“ Take three matches, or better still, a number of strips of wood, place them one above the other. Bend them as you bent the rod of paper and watch what happens. Now remember that the layers of the earth’s crust, which bend and crumple and stretch and break, when they are folded in the same way, form the outside skin of a globe of liquid, which is under great pressure and determined to escape through every possible outlet. Sometimes the crust of the earth cracks right through at the top of the fold, and you have a great outpouring of lava, and a whole chain of volcanoes; like the great world ridge which forms the Andes and Rocky Mountains.

“ Bend another three matches. Watch how they are displaced with regard to one another. The top match breaks, the second half breaks, and the inside one is crumpled. See how they have slipped over one another, and notice especially the empty spaces that are now left between them. Now if a

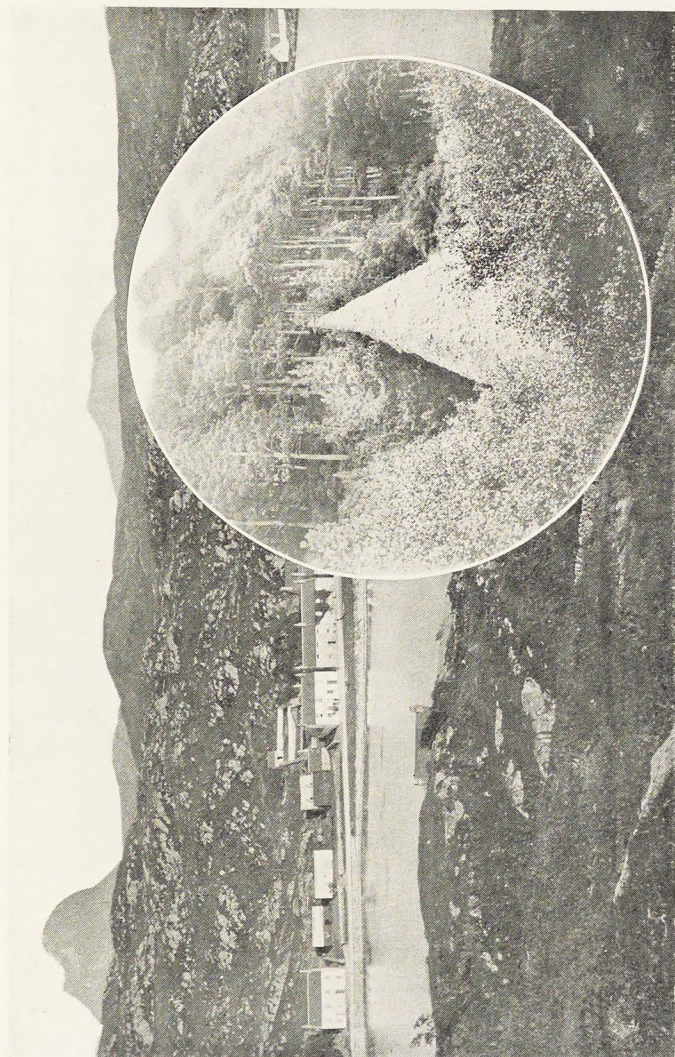


Photo Geological Survey

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Plateau of Lewisian Gneiss S. E. of Loch Inver, Sutherlandshire. The pyramid of boulder clay in the inset is surmounted by a stone which has prevented the pillar from being washed away by the rain along with the rest of the bed of clay which once filled the valley.



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liquid under great pressure were trying to break through this skin, you can imagine how it would burst right up through a broken layer, fill all the empty spaces between two bent layers that had been forced out of position, flow along until it found a crack or a weak place in an overlying layer and finally escape to the surface. This is the story of the injected igneous rocks as traced by geologists.

“The rocks inside the part of the earth’s crust which is being bent upward into mountains by the tremendous force of the world’s contraction pushing the opposite sides of a continent together, are greatly altered by the terrible ordeal they have gone through. They have been subjected not only to unthinkably great pressure, but to terrific heat. Their very nature is changed. All are compressed and hardened, some are as crystalline as if they had been melted, others are shattered and squeezed into slates, with a cleavage at right angles to the direction of the compressing force.

“The landscape shown in this picture is the oldest in the world, and is a striking illustration of the effect of denudation. The mountains Suilven and Cul Mor in the distance, still nearly three thousand feet high, are the last remaining portions of a great cake of Torridonian sandstone at least ten thousand feet thick which once rested over the whole of this country.”

Chapter the Thirteenth

*Down the Enterkin—The Silent Victory of
the Grass*



HAVE to see an old patient of mine who lives down near Drumlanrig," said the doctor, one morning, "and if you like to come with me, Ronald, you will enjoy the walk, and see a new bit of the country."

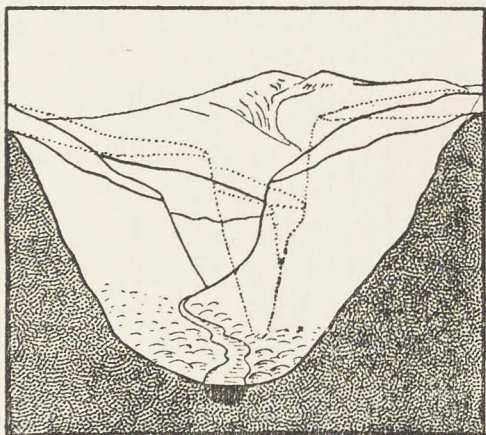
They climbed to the head of the Enterkin Pass, and were soon descending the deep mountain valley with rocky hills on each side of them.

"Do you really mean to tell me," said Ronald, "that this tiny little brook has cut out the whole of this valley? I can quite believe that a big river like the Clyde can wear away a great valley for itself, but this burn seems far too small to have cut such a big hole through the hills."

"I am not surprised at your asking that question," said the doctor, "because geologists recognise that there were several causes which have made the

Down the Enterkin

valleys. Some of the largest are mainly the work of the glaciers; but most of our valleys have actually been cut out by the streams which we see running down their centres to-day. These valleys have grown wider and wider by the crumbling away



River gorge (originally V-shaped, as shown by dotted lines) widened by glacial action into U-shaped valley.

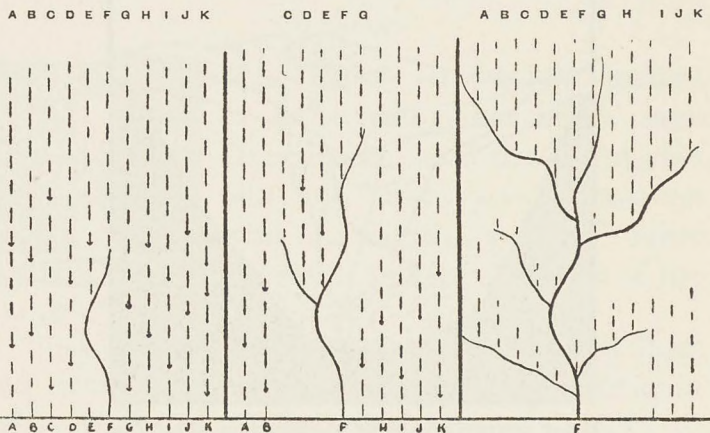
of the rocks on each side, and by the work of the stream constantly sawing away at the foot of the cliffs, and undermining them.

“This glen was first cut out of the central table-land by a mountain torrent, then broadened by a glacier, and afterwards deepened by the burn you see flowing through it now.”

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“How does a river begin, doctor?”

“You will notice, Ronald, the number of little water courses on the hillside; people here call them ‘scaurs.’ They are merely scratches on the side of the hill, and after a heavy rain, you will see the water running down them. One part of the



Beginning of a River.—On an even slope the rain water would run straight down in a number of small streamlets (*A* to *K*).

Suppose a boulder or some other obstruction causes streamlet *F* to swerve from its course far enough for it to intercept the waters of *E*. The united waters of *E* and *F* would cut out a much deeper channel than any other of the single streamlets.

Now let *G* be diverted into *F* and the combined *E*, *F*, *G* will cut a channel so deep that the other streamlets *D*, *C*, *B*, *A*, etc., will drain into it sideways, and soon the one river will drain the whole region.

ground happens to be lower than the rest. The rain runs into this hollow, and the force of the



The Road up the Enterkin Pass
Stephen Reid



Down the Enterkin

water running down it, carries away some of the sand and small stones, making the hollow deeper. The rain, which would otherwise have gone straight on down the hillside, runs sideways into this hollow, and in its turn helps to deepen the bed of the little stream, which has now been formed. As the hollow gets deeper, the stones and broken bits of the rock slip in from the sides, which have been undermined by the little stream. These stones fall into the stream itself, and are carried away by it.

"If you look along the floor of this valley, you will see a heap of broken pieces of rock at every place where one of these scaurs joins the stream. These fragments have been carried down the hillside by the water rushing between the banks of the narrow scaur. Once free of the scaur, the water can escape into the main stream, without the trouble of carrying the stones along with it, so it leaves them piled in a heap.

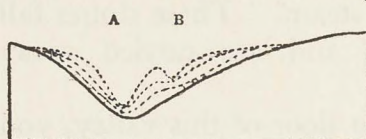
"When the snow melts in the spring time, there is a tremendous quantity of water that wants to rush down from the hills into the sea. This causes the stream to swell and rise several feet higher in the glen, and to carry away with it, all the piles of stones which have been brought down to its side by the little mountain torrents."

"But, doctor," said Ronald, "stones don't float.

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They always sink to the bottom of the water. How can the river carry them away?"

"You are quite right so far," said the doctor. "The stones don't actually float, but they are carried along the bottom of the river by the force of the water, and rolled over and over in its bed on the way down to the sea. All the stones in the world were once rough pieces broken off the



Cross section.—Streamlets *A* and *B* are flowing parallel to one another down the slope. *A* grows larger, and gradually the ridge between it and *B* is eaten away (as shown by dotted lines), and the two gullies form one valley.

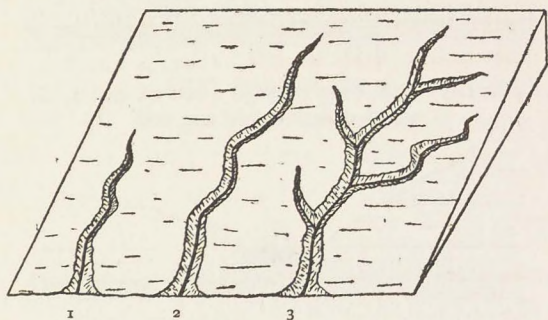
solid rock, and you can always tell whether a stone has travelled far, by seeing whether its edges are rough and sharp, or whether they have been ground away and smoothed by the action of water.

"In the valley here, there are beds of gravel on each side of the stream. High up on its banks quite large stones have been left by the river when it was in flood. If you look at one of them closely, you will notice that the edges are all rough, and at once realise that it is a piece split off a big rock. If, on the other hand, you look at these small pebbles in the bed of the stream, you will see how beautifully rounded they are.

"The work of the river is to roll the stones down

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to the sea. It turns them over sideways, just as you would roll over a big stone that was too heavy for you to lift. This is why you will always find the stones in the bed of a river, lying with their longest diameter along the



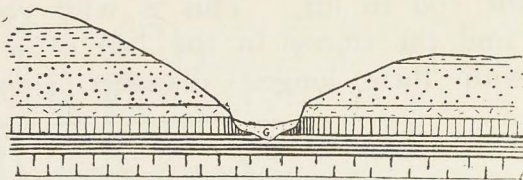
Growth of a River.—Geologists regard a river as beginning at its mouth, and gradually eating its way back into the land. It grows by sending out branches from each side, and draining the water from a larger and larger area of country and swallowing up smaller streams. A river is like a tree with its roots in the ocean growing upward into the land.

channel, and with their thinnest edge pointing up the stream, like a ship at anchor which always rides with its bow facing the tide.

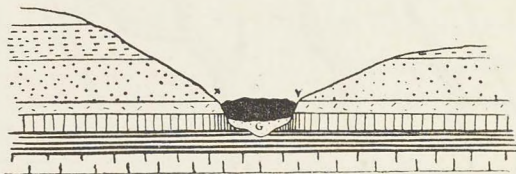
“These details seem of no consequence, but if a geologist comes across a bank of gravel thousands of years after the river which laid it down had disappeared, they would enable him to say: ‘these stones were placed here by a stream which flowed along their longest diameters, and from the

Secrets of the Hills

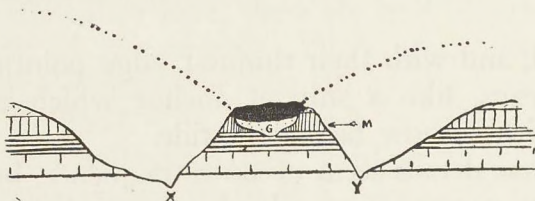
direction to which their thinnest edges and slope point.'



The river is flowing through a bed of gravel, *G*, which contains gold nuggets.



A stream of lava rolls into and fills up the valley and the bed of the river. The tributaries of the old river coming from the hills on the left, flow along the edge of the cake of lava and unite to form new river *X*. Those coming from the right form the new river *Y*.



The new rivers *X* and *Y* cut valleys for themselves into the sides of the old hills, which they undermine and wash away. The lava, being much harder, preserves the gravel and other soft rocks under it. The old river gravel *G* is now lying on the top of a hill, and geologists having calculated where it ought to be found inside the hill, drive in the mine *M* and extract the gold.

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"By these simple indications geologists in America were able to calculate the position of the bed of a river, which had been buried under a mass of volcanic rocks that had been poured up out of the earth thousands of years ago. Miners drove a tunnel into the side of the mountain to the place where they thought they would find the bed of the old river. They found the old river channel, mined out all the gravel, which was very rich in gold dust and small nuggets. Then they washed out the gold and made a large fortune.

"Look, now," said the doctor, "there is quite a large flat space at the foot of the valley, with room enough for a square field on each side of the stream.

"All the soil here has been brought down by the river at one time or another. As the valley broadens out, the water spreads over the surface and of course becomes shallow. It is therefore only able to carry small stones and grains of sand with it, and, besides, it flows much more slowly. The slower the current, the less power it has to roll the stones along with it, so they drop out and fall to the bottom. Then the mud falls into the spaces between the stones, and is held there, and fertile soil begins to be formed.

"Have you ever thought what soil is, Ronald?"

"Yes, soil is just broken up rock, doctor."

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"You are quite right in one sense, Ronald, and terribly far wrong in another. There is all the difference in the world between a cubic inch of broken rock and a cubic inch of soil. In passing from one to the other you have crossed a gulf of millions of years. You have left an old world behind you, and entered an entirely new one. Everything that can be said about an inch of rock could be written on one sheet of paper. You state its weight, its colour, its chemical composition, and microscopic structure, and its probable relations to other rocks. But that is the end of the story, and you must stop. A cubic inch of soil is a world in itself. Millions of animals, which we call bacteria, are living in it. It is their nursery, their graveyard, their home, their factory, and their battlefield. Before you finish their story you will have written the whole history of the universe.

"Three tiny grass blades are sprouting there from a crack in the rock. That is the battle flag of the Empire of Life. Let us pull up a tuft of grass and see what it is doing on the stoney hillside. Its roots go branching down between the stones and prevent the grains of sand which lodge there being washed out again by the rain.

"This network formed of roots and grains of rock retains the water like a sponge. The imprisoned water works away at the grains of sand,

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breaking them up still further, and dissolving out certain substances.

"The plant wants these substances for food. Every root is a little pipe through which the plant sucks up the water, which has some of the dissolved rock in it. The plant digests this solution, breathes out the water, and builds the mineral substances into its own body, along with other food which it takes out of the air. So the plant grows.

"The plant has the power of making vegetable acids; these help the water to dissolve the rock still faster, and make more food for the plant to eat. Then animals come to eat the plant, and they in turn leave manure. The manure contains animal acids which also dissolve the rock. When the leaves or stems of the plant die, they are eaten by earth worms. These worms are always working away, tunnelling through the broken bits of rock, and turning them over and over, so that the water, the air, the sun's heat, the frost, the vegetable acids, and the animal acids, can attack the grains of rock and break them down smaller and smaller. Then countless armies of bacteria set to work and prepare the soil for other plants to grow in it."

"Oh dear," said Ronald, "please say that again! First of all, I thought it was like the House that

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Jack built, and now it sounds as if the whole world was a huge menagerie, with all the wild animals let loose, so that everybody is always eating up everybody else. I know that animals are always eating, but you want me to believe that plants and water are always eating, and being eaten too. There is no rest, and no beginning, and no end."

"You can begin anywhere you like," said the doctor. "Suppose we try to put it like the House that Jack built. Let us start:—

'This is the rock that the world was made of.

This is the sun that cracked the rock that the world was made of.

This is the water that lay in the crack that dissolved the rock that the world was made of.

This is the seed that fell into the crack, and grew into the plant, that sucked up the water, that dissolved the rock that the world was made of.

This is the animal that ate the plant, and so on for ever and ever!'

"Yes," continued the doctor, "but in a sense the very rocks are eating and growing too. While these rocks we see are being slowly broken up and carried away, other rocks are being formed underneath the sea, out of the sands which the rivers are always carrying down to it. These new rocks are building up into themselves, not only the remains of older rocks, but the remains of animals

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and plants which have been brought down by the rivers along with the sand and mud."

"But," said Ronald, "if you talk of rocks growing, where are you going to stop?"

"We have never begun," said the doctor, "and we're never going to stop. The whole universe has started on a journey that goes on for ever and ever. We are travelling by express train on an endless railway. The engine is snorting out, 'Can't stop! no stop! Can't stop!' while at every station the guard cries, 'Change here! Change here! Change here for everywhere.'"

"You cannot lay your finger on a mountain, or a blade of grass, or even on a grain of sand and say this is dead, this is at rest! The smallest bit of the broken up rotten remains of a dead leaf is like a soldier, for ever standing at attention, constantly receiving and obeying orders that come to it from the Great Commander. It has a definite piece of work to do, and it is always doing it.

"The whole world is turning round and round and whirling along its orbit round the sun. The sun, along with us and all the planets, is rushing round and round the centre of the universe, and the whole universe is flying through space we know not where."

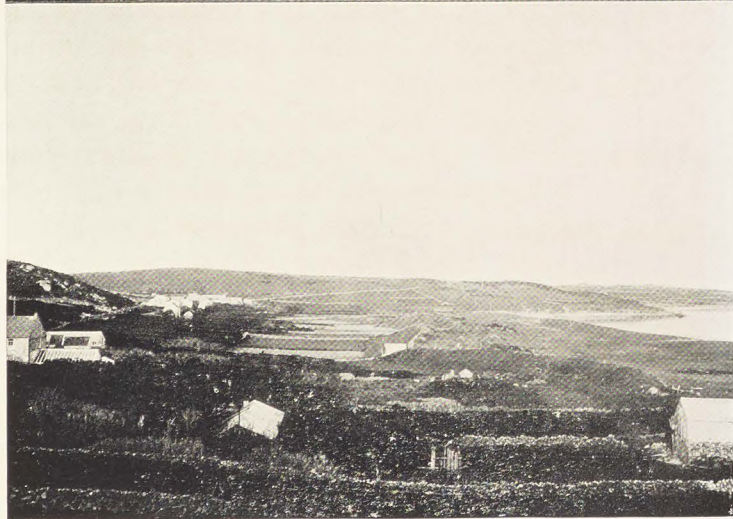
Ronald felt awed by the eeriness of the glen. Enterkin Pass is a great wedge cut out of the

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heart of the mountain. Take a bound volume of music and holding it somewhat open look down into it. The binder's thread might represent the burn flowing at the foot of the valley, and the printed notes on the bars of music might represent people moving on the sides of the glen.

The sheep far up on the hillsides looked to Ronald like mushrooms that moved occasionally. Fleecy white cloudsswam in the blue sky above, and a solitary long-winged heron sailed majestically beneath the clouds. The silence was intense. They had entered a world which contained no other human beings. A stunted rowan tree, uprooted by the winter gale, had fallen across the stream and sprouted again. It formed a natural bridge over a chasm in the rocks through which the burn was splashing itself. Ronald felt so awed that the splashing of the noisy little waterfall was a welcome relief. He scrambled on to the tree trunk, dangled his legs above the spray, and presently the doctor came and sat on the tree root beside him.

"You know the old story, Ronald, of the lion who owed his life to a mouse. He had spared the little creature when he might have killed it, and long afterwards the mouse found the lion caught in the hunter's net, and recognising his benefactor, gnawed through the cords and set the lion free.



1. Masses of loose sand blown in from the sea-shore overwhelming the cultivated lands. 2. St. Martin's, Scilly Isles. Bar of blown sand retained by grass (seen on the right) keeping out the sea from the head of the bay. The land behind, which has been thus reclaimed, is very valuable for growing early spring flowers.



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"Did you ever think of a mountain owing its preservation to blades of grass? You look up at these old weather-beaten heights, and say they are worth next to nothing, because the grass is so scanty that it is a hard day's work for a sheep to find its dinner on ten acres.

"I see on that bare hillside the fighting line in the great battle between the army of life and the forces of destruction. Ages ago the flying scouts of the empire of living things, the advance guard of the civilisation we depend on—in the form of tiny grass seeds borne on the wind—settled on the edge of the brook there, and conquered an inch of the desolate hillside. Spreading their rootlets (like barbed wire entanglements) they caught the little grains of broken rock brought down by the rain, held them prisoners, and fed on them. Next year these grass plants sent forth their regiments of seeds to fly round the rocky ground and try to discover a crack to rest and grow in.

"Inch by inch the silent army pushed forward its entrenchments over the enemy's country, hoisting a little green flag as each grain of soil was added to the empire of life. Our soldiers and statesmen glory in "painting the map of the world red," but the real constructive work of civilisation lies in clothing the mountains and making the desert green.

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“Look up and down the valley now, and see how quickly the ‘scaurs’ are cutting their way back into the mountain, wherever the grass has once been removed. I myself can remember the time when some of those great empty channels were mere scratches on the green hillside, though they have now cut notches out of it, ten feet deep and forty feet wide. The grass is an almost perfect shield against sun and frost and heavy rain. All along the ridge of the hill there, the grass is contesting each inch of the ground on the the mountain top, and saying to the forces of destruction, ‘thus far shalt thou come but no farther.’

“I have often been astonished when cutting the turf off the top of a rock to look for glacial markings, to see how marvellously the scratchings have been preserved for so many thousands of years.

“The grass is not only the preserver of mountains, but the conqueror of the sea.

“All round the margin of a sandy bay, you can watch the grass plants working night and day, sending forth swarms of seeds to invade the territory of their enemy the sea, whenever the tide goes out. Every wind that blows the sand inland bears some of the grass seeds with it, and wherever the sand grains fall, the grass seeds attempt to annex them for the Empire of Life.

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"The drifting sands, streaming across the country, are caught amongst the tough stalks of the bent-grass, and as every successive wind brings its layer of sand, new grass blades push their way up through it and bind it down to the land. All the sand hills which surround our coast have been caught by the grass and anchored down layer by layer. Miles of land have thus been raised above the level of the sea and added to the area of our country."

Chapter the Fourteenth

Sandstone Quarry and Fossils



RONALD often accompanied the doctor on his longer trips and was keen to see all he could.

"There is a sandstone quarry here," said the doctor, "that we might have a look at while the horse is getting a drink and a rest. I know the manager well, and he often sends up to tell me when they find anything remarkable. The rocks are quite different from those at Leadhills. Here you will notice that the rocks are all laid in layers one on the top of another."

Ronald looked round and saw the great walls of rock on all sides of him, rising higher than any houses he had ever seen. In some places the wall of rock rose straight up, just like the side of a house with no windows and no cracks between the stones.

Presently a horn was sounded, and the men everywhere laid down their tools and put on their coats.

Sandstone Quarry and Fossils

"They are just going to blast," said the doctor,
"and that is a warning for us all to get to a



The Twins, Bluff City, Utah. Observe how the jointing has allowed the weather to decay away the whole cliff, till only these two pillars remain. Their height (from the bottom of the cliff) is 275 feet.

place of safety."

"What is a blast?" said Ronald.

"The principle of the explosive," said the doctor,

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“is that when any substance changes its form from being a solid, into a gas, it takes up a very great deal more room than it did before.

“Some substances burn up very suddenly ; in less than a second they explode, as we say, and go entirely into smoke or gas. It is this force that we use in shooting. The gunpowder is placed, as you know, in a gun, a spark is applied, and the force generated by the gunpowder suddenly burning up, is so great that it drives out a bullet with tremendous force.

“In order to break up the rocks, the men bore a hole into the solid rock, fill it with gunpowder, and set fire to it. The force of the explosion breaks up the rock, and the men have only to go and pick up the pieces.

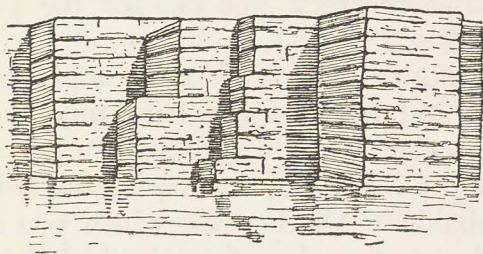
“Whenever you get a chance of looking into a big hole cut into the earth, you should always examine it very carefully. It is just by looking at the different rocks, lying one on top of the other, that the geologists have discovered how the earth was made. If you look closely at this rock, you will see that there are cracks running all across it.

“Suppose you had a great book closed, with the edges of the pages towards you, you know that if you cut through a leaf, the piece you cut off would be quite loose, and come away in your hand. The layers of rock in this quarry are like

Sandstone Quarry and Fossils

the pages of an immense book. At first you might think it was absolutely solid, but if you look carefully, you can trace the cracks. The layers of rock vary in thickness, from less than an inch to five or ten feet, but a great many of them are from six inches to two feet thick.

“When you try to split a piece of wood, Ronald, if you put the axe down in the direction in which the tree has grown, that is, in a line



Jointed Sandstone.

with the grain, it splits quite easily, but if you try to cut or break it across the grain, it will not split; you have to cut through every separate fibre. Sandstone rocks can be split in the same way, and it is this cleavage which makes them easy to cut. In addition to the cleavage between the successive layers, every rock has a system of cracks, due to contraction while cooling: this is called its ‘jointing.’ In sandstone the jointing takes the form of two sets of parallel cracks at

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right angles to one another. These cut up every layer into a great number of square cakes lying ready to be removed by the quarry-men. It is for this reason that it gets its other name of 'Freestone,' because it comes away freely. Every kind of rock has its own peculiar kind of 'jointing,' which is in many ways akin to crystallisation, and forms a ready means of identifying the rock.

"Look at the rock, you can see the grains of sand in it."

"If I put a heap of sand together," said Ronald, "and left it for a long time, would it become a rock?"

"It might," said the doctor, "though it is not at all probable. All the rock which you see here is formed out of grains of sand which have been washed down by a river at some time. This rock was probably formed at the bottom of a great lake. Every time the rivers were flooded by heavy rains, they brought down great quantities of sand with them. When the water of the river reached the lake, it could flow no farther, so it stopped, and the grains of sand dropped out of it on to the floor of the lake, and were there piled up, one on top of the other.

"In some places these sandstone rocks are several hundred feet deep. Water was constantly

Sandstone Quarry and Fossils

circulating up and down among the sand grains, and leaving behind it small quantities of lime which it had dissolved out of broken shells or the bones of animals which had also been brought down by the rivers. These small quantities of lime and other minerals cemented the sand grains together. The tremendous weight of these layers of sand and mud, piled one above the other, crushed the sand so close together that it became solid rock as you now see it. After lying under the water for many thousands of years, the floor of this great lake has been raised up again until it became dry land.

"Some years ago they found a very interesting fossil tree here, and they have still part of it in front of the manager's house. We will go and have a look at it.

"You can see at once that it is a tree. Here the bark has been left on, and there large pieces have been stripped off. At this place, where the trunk has been cut across, you can see the rings in the tree.

"It is quite possible, by studying these fossils carefully, to tell what kind of tree it was, although, of course, there is not a particle of actual wood left. It is all mineralised through and through, almost the same as in the rest of the quarry rock.

"This tree was growing thousands and

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thousands of years ago on the side of a river. It died and fell into the stream, and was carried down, along with all the mud and stones, into the bottom of the lake.

"It was buried in the sand and left there until it is now changed into stone.

"The manager tells me that they have found a bed of rock showing wave-marking like those on the seashore, where the tide has been. You have often seen the ripple-marks due to currents left upon the sand, and if I can show you these marks in the solid sandstone, that will prove that this has once been a shore. Look at the rock here; you can quite easily see the wave-markings. These ripple-markings are only, of course, found in the shallow water.

"One sunny day, thousands and thousands of years ago, the wind rippled the waters of the incoming tide, when the sandstone rock on which we are standing was loose sand on the seashore. When the tide went out for the last time, the marks of the ripples were left on the sand, just as we see them here in this solid rock to-day.

"You remember how Robinson Crusoe found the footprints on the shore, and knew by it that some man with bare feet must have walked across that place since the tide went out, and that this

Sandstone Quarry and Fossils

led him to look out for other signs of human visitors to his island.

"In the same way footprints in the rock, which could not have been caused by any bird or animal now living on the earth, have led geologists to look for other signs and remains of the animal that must have made the footprints. Little by little so much evidence has been collected, that although the last of these extinct animals must have died out long before there was any man living on the earth, we can tell how big they were, what they looked like, what they lived on, and, in fact, all the important things about them.

"Before the great sinking of the earth took place, this rock was the sand of the shore of a great lake. The wind was blowing the water into little waves, and they made wave marks in the sand. That part of the earth's surface sank, and instead of being shallow, it was now in deep water, and great quantities of mud were washed down, and formed a new layer of sand and mud, on the top of these wave marks in the sand: and now when the rocks which this new layer of sand formed have been taken away, we see this sea-shore just exactly as it was hundreds of thousands of years ago."

"Yes, there is a very interesting thing here, Doctor," said the manager, who had just come up.

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"This, I think, is one of the footprints left by a large bird."

The doctor and Ronald went down on their knees and examined it carefully, finding the manager was quite right, for they traced several prints of a large bird.

"From these footprints," said the doctor, "we can tell what size of a bird it was, and what were its habits, because every animal's body is adapted to the way in which the animal lives.

"By examining a bird's foot, we know whether it is in the habit of flying and resting on the branches of trees; or walking on the ground, and scraping for its food, living like a hen; or swimming about like a duck.

"The dead bodies of animals which lived in those bygone ages would also be washed down along with the mud of the river, and though all the soft parts of their bodies would be dissolved without leaving any trace, the bones would be turned into fossils, and in this way we can tell what kind of animals lived on the earth, hundreds of thousands of years before man was created."

"How do we know what kind of people lived hundreds of years ago?" asked Ronald.

"History consists of the stories that have been handed down from one generation to another, and in quite recent times books of history have been

Sandstone Quarry and Fossils

written by various men in many countries. This last century we have learned a great deal more about the people who lived long ago by examining the remains which they have left behind them. Two towns, called Pompeii and Herculaneum, which lay at the foot of Mount Vesuvius, were one day buried underneath a great shower of ashes from the burning mountain.

“The place where these towns were, was well known. Many years ago a company of learned men, who were interested in studying the life of the old Romans, determined to dig away all the ashes, and there they found the houses, the streets, and the bodies of the people, who had been overtaken while going about their daily work eighteen hundred years ago. They found the body of a Roman soldier clad in full armour, with helmet and spear, as he stood on duty. Remaining nobly at his post, he had been buried amidst the falling showers of dust.

“Many articles of furniture, pots and pans, and everything else used in the daily life of the Romans, were also preserved in the ruins of these buried cities, so that we know almost all that can be known about these people. We have obtained more knowledge of Roman life from these excavations, than from all their histories and books

“Excavations in Egypt have laid bare old cities,

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temples, and tombs which had been covered by the drifting sands of the deserts, and our museums have now a great many relics of these ancient times. The fossils in the rocks tell us, much in the same way, the history of the world.

"The town of Pompeii preserved under its shower of ashes, and the old temples of Egypt sealed up in their sands, are just very, very new fossils. The old fossils tell us about the animals that lived on the earth millions of years ago in the same way that the excavations of these buried cities tell us of the life of their inhabitants two thousand years ago.

"The most interesting, because the newest fossil in the world, is in the museum at St Petersburg. It is a mammoth or woolly-haired elephant, which was found in Siberia. This animal has long been extinct. No one knows how many thousands of years it is since this one lost its life, but the mass of ice-cold mud into which it had fallen, had afterwards frozen over its dead body and preserved it so perfectly, that Doctor Hertz found fragments of its last dinner still sticking between its teeth, and the well-preserved remains of a recent meal in its stomach. The flesh of this mammoth was so fresh that after the mud had been removed and the sun had had time to thaw it, the native dogs greedily ate it. If the natives had not dug away the frozen mud which covered it, the mammoth might have

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been preserved in this natural cold-storage vault for many thousands of years to come. Scientists could not account for the body of an elephant being found so very far north. Some supposed that it had been carried over a thousand miles by a great river; others said this was quite impossible, and denied that it was an elephant. It was very carefully examined. Pine needles were found sticking between its teeth, which showed that it had been feeding on the young branches of fir trees, and thick woolly hair coated its body. This proved not only that the elephant had lived in the very place where it was found, but that the climate had become colder and colder so gradually that succeeding generations of elephants had had time to adapt themselves to their surroundings by growing thick woolly hair to keep out the cold, and learning how to live on pine trees. The body of a woolly haired rhinoceros was afterwards found in the same district. A well-preserved skeleton of the same species of mammoth was recently discovered during the digging out of the foundations for the *Daily Chronicle* Offices in Fleet Street, London. From the depth at which it was found and the nature of the deposits lying above it, this mammoth must have been buried many thousands of years before the Romans came to Britain."

Chapter the Fifteenth

A Visit to a Coal Mine



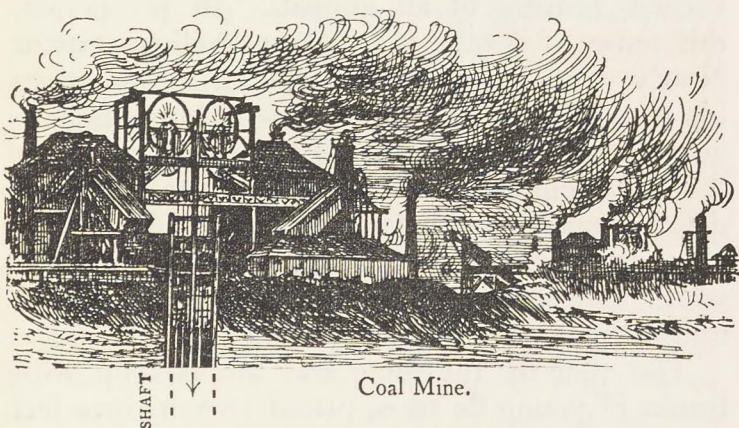
HE doctor had promised to visit an old patient, the wife of a colliery manager, and as Ronald was very anxious to see a coal mine, he agreed to take the boy with him. Ronald had often seen the coal pits in the distance when travelling by train. He had watched the great pulley wheels whirling round and round, and had wondered what it would be like to go deep down into the earth.

The doctor called at the colliery office and left Ronald in charge of the under-manager, Mr Menzies, who was going underground to inspect part of the workings, and offered to take Ronald with him. He took Ronald into his private office, supplied him with some old clothes for the expedition, and told him to come across to the pit-head when he had dressed himself.

Soon all was ready. They stood under the pit-head, in front of the entrance to the shaft. The

A Visit to a Coal Mine

bell rang, and up came a big wooden box about eight feet high and six feet square. Ronald and Mr Menzies with lighted lamps in their caps, stepped into this "cage," as it is called. The under-manager shouted "all right," and they began to go slowly down. The walls seemed to be running up from them, just as the telegraph posts run past



you when you look out of the railway carriage window.

Ronald had seen lifts in hotels, and had been in one in London, so he was quite used to the sensation of descending, but thought it seemed a long time before the cage stopped. At last, however, the gate was opened, and they stepped out upon the pit bottom.

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Everything was pitch dark, and dirty with coal dust. A narrow railway ran along the floor of the passage, and presently there came a small pony dragging a train of trucks after it. Ronald was told that these ponies are stabled down in the mine, and spend their whole lives there, without ever again seeing the daylight. The horse has the keenest hearing of all animals. In pit ponies, this sense is developed to a marvellous extent. Nearly every miner can tell you of a time when his own life was saved by a pony who refused to go on into a dangerous place, although the miner thought it quite safe. Undoubtedly the ponies can detect dangers long before the men, and a careful miner will leave his work and go and see what is wrong whenever he hears the ponies making an unusual noise.

The roof of the mine was propped up with trunks of young fir trees, placed two or three feet apart on both sides of the roadway.

The whole place was a network of passages. All the coal had been worked out, and the sides of the roads were lined by walls built of rough stones. In the main roads, the overhanging rock had been cut out, in order to make the passage high enough for a man to walk upright.

In some pits, the manager told Ronald, they only work out part of the coal, and leave square

A Visit to a Coal Mine

pillars to support the roof, so that the plan of the pit is like a draught board. The black squares on the board representing the pillars of coal, left in to keep up the roof, and the white squares, the parts where the coal had been worked out.

After the miners have made these passages, and cross-passages, and have removed all the coal except that in the squares supporting the roof, they take this away also, and allow the roof with all the rocks on top of it to settle down.

In many colliery districts this falling in of the roof of the mines causes the houses built above them to tumble; and even where the houses do not fall, cracks appear in the walls, and some of the houses are bent to one side, so that the doors and windows will neither shut nor open properly.

The Douglas pit was worked on the long wall system, the whole of the coal seam being taken out, and wooden props put in to support the roof where the miners were working.

Ronald now found himself in a great underground town with queer streets or passages running off from each side of the tramway on which he was walking.

Every few yards he looked down one of the passages and saw the dull light of a miner's lamp glimmering in the distance. Mr Menzies waited at certain points, till a miner, black of face and

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hands, came and asked some question about his work, or reported something, and then disappeared into the darkness. All the time they could hear the rumble of the small trucks full of coal being dragged to the bottom of the pit shaft. Every now and then they left the main road to inspect some of the places where the men were working.

Passages, passages everywhere. Whenever Mr Menzies had occasion to leave Ronald for a minute, he would tell him not to go away from the place where he stood, as he might wander into some disused part of the mine and lose himself.

Ronald was keenly anxious to see the coal actually in the solid rock, and as they neared the working face of the coal seam, he could hear the sound of the miners' picks, hacking away at the coal. Suddenly a boy passed them, pushing three empty "hutches" or little trucks. Following behind these, they came to where a man was shovelling coal into the "hutches," standing on the tramway and throwing stones and dirt into the empty space behind him.

The seam of coal was about three feet thick. The miners lie sideways on the floor of the mine, and they cut their way about two feet in under the coal. When they have "holed" the seam, as they call it, they bore a series of small holes at the top, between the coal and the overlying sandstone,

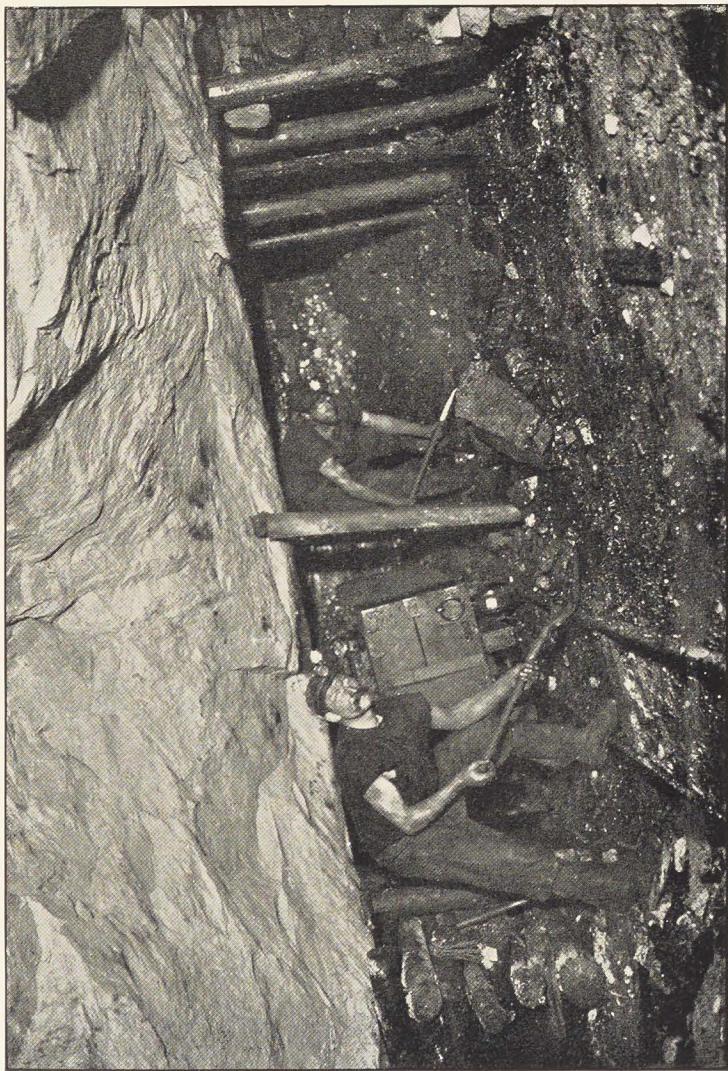


Photo Valentine & Sons, Ltd

Holing the Coal



A Visit to a Coal Mine

which they charge with gunpowder. The explosion which follows blows down the part of the seam which has been undermined, and the coal is then shovelled into small waggons or trucks and taken up out of the pit.

The same work was going on at many different places throughout the mine, and as they passed in the darkness, Ronald often caught sight of smoke and lights, and heard the sound of pick and shovel.

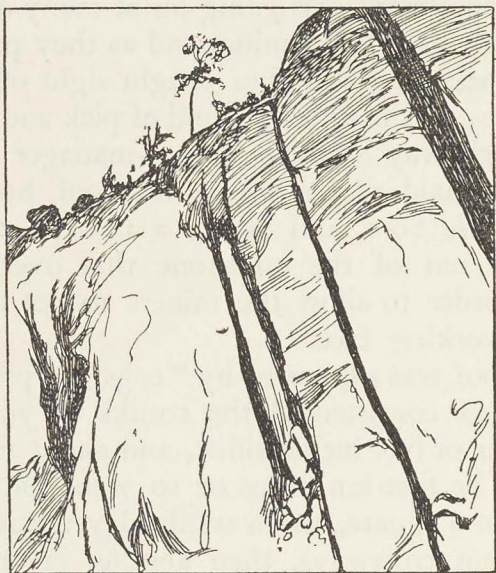
On their way back, the under-manager pointed out to Ronald places where the roof had sunk down to the floor, and where a new passage had been cut out of the sandstone that overlay the coal, in order to allow the miners to get through to the working face.

The roof was supported by "cogs" of pit-props. These cogs consisted of the trunks of young fir trees, four or five inches thick, and about four feet long. The first ten props or so were laid on the ground in a square, and a similar layer was placed upon them crossways, then another layer along, and a third layer across, until they were piled to the height of the roof. In some places, where the roof had settled down, its weight was so great that these logs of wood had been crushed like so many matches, until a pile, formerly six feet high, had been squeezed down into a matting a foot and a half thick.

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As they walked through the mine, Ronald examined the rocks the passages were cut through.

A bed of fireclay lay under the coal seam, and Mr Menzies explained that this was the soil in which grew the marsh plants that formed the coal.



Seams of Coal exposed in Sandstone Cliffs which have been pushed up out of their places till they are nearly perpendicular.

Above was a thin band of iron-stone, covered by a layer of blaes, as black as coal but hard and slaty, and breaking off into flakes, and over this again was a thick bed of sandstone, in every way similar to that which Ronald had seen in the quarry.

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The iron-stone felt very heavy but it looked like ordinary rock, and not in the least like iron, so far as Ronald could see.

Ronald took the hammer and chipped off small pieces of the coal as they walked along past it, just to assure himself that it really was the coal in its natural state, lying there between the rocks.

"The passage we are standing in has been cut through what we call the 'mussel bed,'" said Mr Menzies. "If we look carefully we shall find fossil-mussels. See here is one." He chipped an ob-

ject out of the rock and handed it to Ronald, who saw that it was nearly the shape of a mussel, but a freshwater mussel, such as

is found to-day in rivers and lakes, not one of the mussels that are found in the sea. In a few minutes they found many others, and Ronald filled his pockets with the fossil remains of these shell-fish.

"These fossils," said the manager, "show that there must have been fresh water lying above the coal, because these are not the mussels you



Coal Ball as seen through a Microscope. The stems of the plants are seen cut across. These plant remains have been enclosed in a nodule and preserved from decomposing into ordinary coal.

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are accustomed to, which live in the sea, but cousins of theirs which live in lakes and rivers."

Having finished his inspection, Mr Menzies and Ronald returned to the pit shaft, and though Ronald had found it all very interesting, he felt glad to breathe fresh air and live in the daylight again.



Fossil Fern.

On the way up, Mr Menzies mentioned that he had some fine fossil ferns in his office, and Ronald was eager to see them.

On reaching the office Mr Menzies handed to Ronald what seemed a piece of ordinary shale, but on examining it carefully, the boy traced in it outlines of a fossil fern-leaf.

In another piece was a small fossil branch of a tree, with nuts adhering to it. It had been imbedded in the rock when it was formed ages ago.

On the walls of the office hung maps of the surrounding country, and plans of the mine.

Turning to one of these Mr Menzies said:—

A Visit to a Coal Mine

"This is a section showing the different kinds of rocks the mine goes through.

"There are, as you see, five seams of coal. The two top ones are too thin to work at a profit. But if it had not been for them, we should never have known there was any coal here. You can see the thin top seam in the bank of the river, and it also comes to the surface in the hollow to the east there. It was the discovery of this thin three-inch seam, in the bank of the river, that led the owner of the ground to have a bore put down, in order to see whether there were thicker seams underneath. There was a part of the field beyond the river, where the old people remembered that they used to gather bits of coal when they were children, and a rough piece of ground further on, where they got their coal out by shovelling off about four or five feet of the surface soil. They called this an 'open working.'

"None of the strata lie quite flat, they all 'dip,' as we miners say, into the ground. The angle which the line of the strata makes with the horizontal is called the 'angle of dip.' This angle often remains the same for long distances, and it enables us to tell how far a seam of coal which comes up to the surface here, will be underneath the ground a quarter of a mile away."

"Why have you sunk the pit up here on the

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side of the hill, where you have to go down over six hundred feet to get to the coal, instead of putting it near the river, where you would only need to have gone down one hundred feet?" asked Ronald.

"Principally to get good drainage. How to get rid of the water is the great trouble in coal mines. The river is the boundary of our company's property. If we had sunk the shaft near the top of the seam, and commenced to work out the coal, we should have got on all right to begin with. But as we went on working out the coal and followed the seam as it dipped into the ground, the water, which is always trickling down through the rocks above us into the shaft, would have run back into the places where the miners were working the coal, and drowned them out. By sinking the pit at the lowest part of our coal field, we let all the water run down into a hole at the bottom of the shaft, where one powerful pump sends it all to the surface at once, and so keeps the whole mine dry.

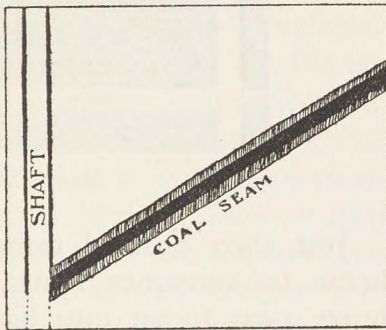
"We also take advantage of the slope to carry the coal to the foot of the shaft, and to haul the empty hutches up to the working place again."

"How is that?" said Ronald.

"Since we start from the lowest part of the

A Visit to a Coal Mine

field and work upward, the working places are always at a higher level than the bottom of the shaft. When the hutches have been filled with coal, they are shoved on to the top end of the rails, and allowed to run down by their own weight. A pulley is fixed at the head of the incline, and a chain is placed round it. The empty hutches at the bottom of the incline are attached to the one end of the chain, and the full hutches to the other. As the full hutches run down, they pull the empty ones up.

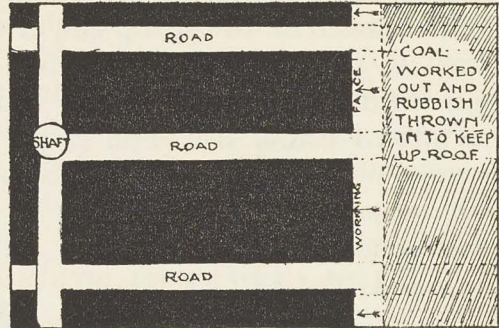


Relation of Shaft to inclined Coal Seam.
Coal Seams often lie horizontally.

“Most of the mines now are worked on the long wall system, the ‘long wall’ being the face of the coal as it is exposed across the whole breadth of the seam. As soon as the shaft is sunk down to the seam level, roads are cut in the coal to the extreme boundary of the field that is to be worked. The miners cut cross roads to join the ends of the main roads, then they turn round and work backward towards the shaft. The whole seam of coal is completely removed and the

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roof is allowed to settle down into the empty space the miners leave behind them."



Plan of Mine.

Just then a maid came from the manager's house to announce lunch, and Ronald had to hurry away to get into his proper clothes again, and make himself presentable.

Chapter the Sixteenth

Dunbar Castle



R THOMSON and his family had arranged to go to Dunbar for their holiday, and as Ronald's vacation had yet a week to run, he was glad to accompany them.

One afternoon they walked to the harbour to get a boat, but the old fisherman warned them that "the wind was blowing from a bad quarter," and said they should wait till it calmed down a little.

Seated on an upturned boat at the quay side the doctor filled his pipe, ramming down the tobacco with a horse shoe nail which he always carried for the purpose.

"Doctor," said Ronald, "I quite believe what you tell me about the wonderful way the world was made, but how can I know it is true? How do you prove it?"

"The proof is all around you. I can only teach you to see it. You cannot become a

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geologist by studying a book, any more than you can become a musician by reading a primer on the theory of music.

"You must learn, like a musician, to 'think with your fingers,' and to be able to recognise a stone wherever you see it, and refer every rock to its place in the geological sequence, just as a musician can recognise and name a note whenever he hears it, and can refer it to its place in the musical scale."

"I am afraid I shall never do that, doctor, because geology seems so horribly complicated."

"On the contrary, geology is the simplest of all the sciences. It requires no tools, but an eye to see, and a mind to recognise what is seen.

"The outside surfaces of most rocks are so changed by 'weathering' that the geologist must carry a hammer to chip off the skin of decayed stone, if he would see what the rock inside really is. A magnifying glass, too, is useful, for it increases the power of the eye, and enables him to see the actual structure of a stone, just as the counting glass enables you to see the separate threads woven into a piece of cloth, and as a more powerful microscope will show you the fibres that have been twisted together to make up these threads.

"The science of geology has been built up by

Dunbar Castle

taking a near and a far view of things, first in space and then in time.

“By the ‘near view’ we see the parts that a thing is built up of, and by the ‘far view’ we see that the thing itself is but a part of a bigger thing.

“Look at the quay wall opposite. It is a part of the harbour—that we can see by the near view—but if we went out yonder to the Bass Rock, we should see the harbour as part of the town—that would be taking the far view.

“By climbing to the top of North Berwick Law yonder, we should get a bird’s-eye view of the whole country for thirty miles round, and be able to trace relationships that we could not possibly see if we remained on low ground. But even this is not a sufficiently comprehensive view for the geologist. He often wants to study the relationships of sets of rocks spread over a much wider area than the eye could possibly cover, so he gets a far far away view of the whole country by accurately marking down the various geological phenomena on a map and then studying the map.

“Again, looking at the harbour wall opposite to us: we see it from here, as a solid surface of smooth stone—that is the far view—but if we walk round to it, we shall find that the wall is

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built up of separate blocks of sandstone—that is the near view.

“If we were unable to get nearer to the quay wall opposite, how could you prove to me, Ronald, that it is built of blocks of stone?”

“It doesn’t need any proof, doctor, you can see the separate blocks quite easily.”

“I cannot see it, Ronald; it is just a plain smooth wall to me. How am I to know it is built up of square stones?”

“Well, doctor, I can see the stones, and I tell you.”

“That is quite sufficient proof for me, Ronald, for I know that your sight is better than mine, and that you can recognise a stone wall when you see it. I have no doubt you have watched builders at work, placing brick on brick, or stone on stone, until the wall was the height required, and you are quite right in thinking that the wall opposite us has been built in the same way.

“Now, Ronald, suppose for a minute that I did not want to take your word for it, and could not walk round to see for myself what the wall was made of, how could you still prove that it was built of square stones?”

Ronald searched his pockets and produced a small telescope. “You can see for yourself if you look through this, doctor.”

Dunbar Castle

The doctor took the telescope, focussed it, and then exclaimed, "Now I can see the square stones. The telescope enables me to get a near view of the wall without going to it, and gives me greater power of seeing. It brings a distant object close enough for me to see it distinctly.

"In the same way a microscope gives us much greater power of seeing small objects. The ordinary eye gives us the far view of a stone, but a powerful microscope is required to give us the near view, and show us exactly what the stone is made of.

"There is still another way, Ronald, in which you could show me how the wall opposite us had come to be there. Can you think of it?"

Ronald puzzled a while and gave it up.

"Well, come here," said the doctor, as he went to the edge of the quay wall where they were sitting, and pointed out that it was built of square blocks of sandstone.

"As both sides of the harbour were most probably built at the same time, we may reasonably conclude that the wall at the other side was built in the same way as this one, and is therefore built of square stones.

"I have asked you these questions, Ronald, as an exercise in geological reasoning. The geologist first asks, 'What is it that I see? is it earth, clay,

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or rock?' then, 'what kind of rock is it?' and the last question is, 'How and when has this rock come to be here?'

"Let us walk round the harbour and examine the remains of the old castle in the same way that a geologist would examine a new bit of country.

"From a distance the whole of the mound on which the ruin stands looks like a single mass of rock, but we now find that part of the mound consists of masonry, and the other part is the solid rock itself.

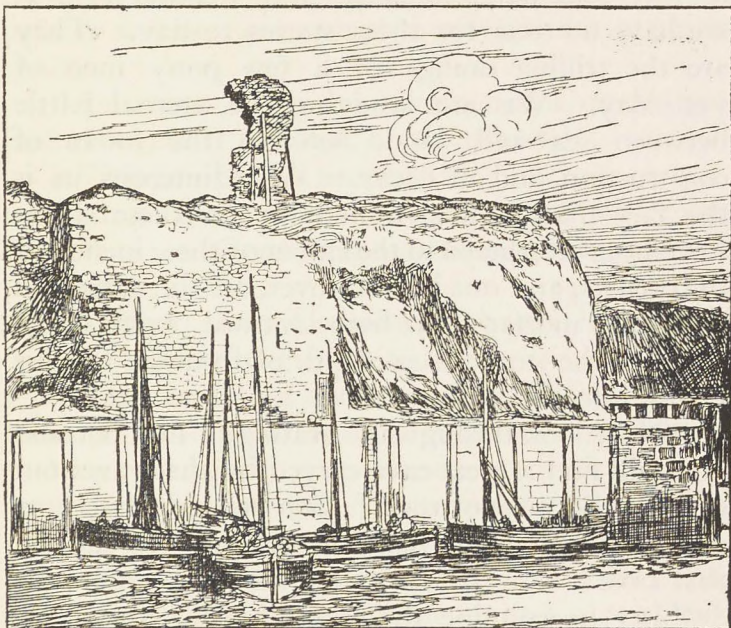
"Instead of this masonry showing a smooth surface like the harbour wall, we see that the stones are rounded, and look more like boulders taken from the shore than hewn stones. As we examine them, however, we find that the inside ends of the stones which are built into the wall are still square and joined together with mortar.

"On the outside of the wall the mortar has not only been washed away by the wind-driven rain, but the stones themselves have been eaten into by wind and rain, till, instead of being square and flat on all sides and jointed together, the ends which are sticking out are rounded and separated from one another, like the ends of your fingers.

"Now, this old wall gives us a means of calculating how fast wind and rain can eat away stone. We know from history that Dunbar Castle was built by Earl Gospatric six years after

Dunbar Castle

the Norman Conquest. It was dismantled in 1568, after the flight of Bothwell, its last warrior-lord, who brought Mary Queen of Scots here,



Dunbar Castle (near view).

after he had captured her on the road from Glasgow to Edinburgh, to hold her captive till she married him. It was from this place that Edward II. escaped in a fishing boat after his defeat at Bannockburn, and here, too, Oliver

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Cromwell won his great victory over the Scots under General Leslie. Every stone of this old pile could tell its tale of siege, and storming party, of love and hate, romance and treachery. But we have no time for these stories to-day. They are the trifling doings of a few puny men of yesterday. We are studying the eternal battle between sea and land, between the forces of construction and of decay. What interests us is the fact that in five hundred years these stones have been weathered to the extent of three inches off the corners, and one inch all over, off the ends, and that the mortar has been washed away from between the stones to a depth of from six to nine inches into the wall.

“Now look through the grating in the door and you will find a great cave carved by the waves out of this solid mass of rock. Can you calculate how many thousands of years the sea took to cut out that cave?”

“Let us examine the rock on which the castle is built.”

“Oh, what’s the use of doing that,” said Ronald. “I want to climb up into the ruin and see exactly how they shot out of these two round holes at each side of the gateway. Anybody can see that the castle is built on a foundation of red sandstone, the same as the stones it is built of.”

Dunbar Castle

"Are you sure of that, Ronald?" said the doctor.

"Yes, quite sure, look at it for yourself," said Ronald, as he kicked the rock with his foot. "That is red sandstone just like the rocks on the shore, and the same sandstone that the castle is built of."

"That is sandstone, I admit, but what do you call the rock at the level of your head?"

"This is just the same."

"Look again, Ronald, and tell me where are the lines of stratification between the different layers?"

"Well, doctor, this is red rock too, but I cannot see any lines of cleavage."

"Take my hammer and knock off a chip of this rock and a chip of the sandstone, and look at them both together."

Ronald soon struck off a corner of the sandstone, but he found the other rock very much harder. He hammered and hammered but the rock would not break. Seeing the doctor smile he took both hands to it and battered away at the cliff with all his might until the hammer head flew off.

"I'm afraid," remarked the doctor, as he fixed on the hammer head, "that rock does not know you, Ronald. Watch and I will show you how to talk to it." A sharp slanting blow from the square edge of the hammer sent a chip of rock flying.

Secrets of the Hills

"Now, Ronald, you see this rock is not really red, but dark grey-green. It was only the outside that was stained with iron out of the red sandstone. Look at it through the glass and tell me what it is made of?"

"I don't know, doctor. It is not sandstone anyway."

"That rock is called 'basalt.' It is composed of minerals which have crystallised out of a mass of molten rock which has welled up from inside the earth.

"This distinction between fire-formed rocks like basalt, and water-formed rocks like sandstone, is the foundation of geology. Early geologists were actually divided into two schools: the 'Neptunists,' who said 'all the rocks have been made by water'; and the 'Plutonists,' who said 'some rocks have been made by fire.'

"Whenever you come to a rock, Ronald, ask yourself whether it has been melted by fire, or built up by water? If it shows no layers or lines of stratification, but has a compact glassy surface, and rings solid when struck, more especially if it includes small crystals and looks as if it had been melted, you may be certain it has been formed by heat inside the earth.

"If, on the other hand, you can trace the lines of stratification running along the face of the rock,



Photo Geological Survey

Volcanic agglomerate containing ejected blocks of sandstone which have fallen back into the throat of the volcano.

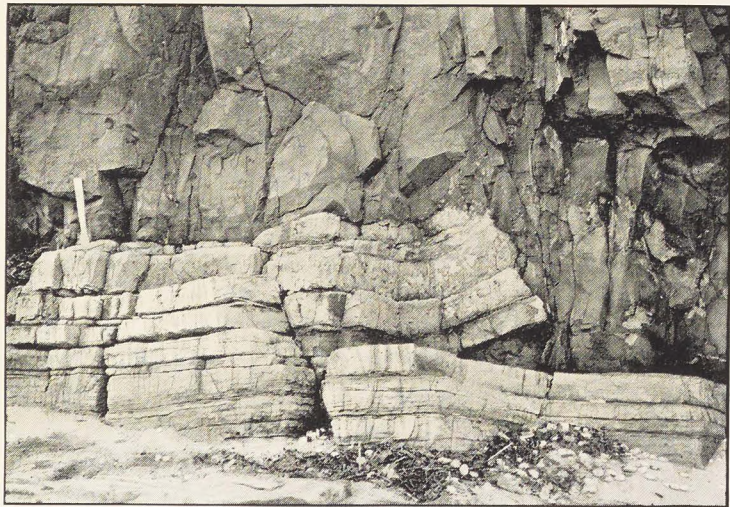


Photo Geological Survey

The dark basalt rock on top has been forced in between the layers of sandstone. Note how the sandstone on the right has been caught up and bent, and the top portion of it melted by the inflowing mass of basalt lava.



Dunbar Castle

and distinguish the different layers of which it has been built, you will be quite safe in saying it has been formed by water.

"Now let us walk along and look at the rock at the other side of the door. Is it sandstone, or is it basalt?"

Ronald didn't want to be wrong again, so he took the hammer and chipped off several bits of the rock, and examined them with the magnifying glass before he spoke.

"I don't know what to call it, doctor. It is not basalt, because there are no crystals, and it is not sandstone, because, though it looks sandy, it is not built up of layers, and there are all kinds of other stones scattered about in it as well."

"Well, has this rock been formed by fire or by water?"

"I don't know, doctor, I don't think it has been formed by water, because I cannot see any layers, and I don't think it has been made by fire, because it has never been properly melted together."

"It is called volcanic agglomerate or ash, or breccia," said the doctor.

"Then how has it been made?" asked Ronald.

"We know that the red sandstone was laid down layer on layer at the bottom of a huge lake that covered the greater part of Scotland, but the basalt and the pudding stone are as foreign to the

Secrets of the Hills

sandstone as the masonry of the old castle, or the wooden door, or the white canvas life-buoy for that matter."

"If this agglomerate is foreign to the other rocks, doctor, how did it get here?"

"It was shot up out of the throat of a volcano, which during the carboniferous period burst through the bottom of the lake where these beds of old red sandstone had been laid down."

"How can you tell that, doctor?"

"Because it looks like a big cinder heap, and cinders can only have come from a volcano.



Neck occupied by Agglomerate.

Look at these angular bits of rock embedded in the agglomerate.

They cannot have been rolled about in the bed of a river and carried here by water, because all their corners are sharp and freshly broken, and have not been rounded in any way. They must have fallen into a mass of cooling cinder pudding, immediately after they were broken off their parent rock."

"How do you know it fell into a cooling pudding?"

"Break off a bit and I'll show you."

Ronald proceeded to break off the corner of an included block but found he had tackled a much

Dunbar Castle

harder job than he had bargained for. It looked like a bit of Old Red Sandstone, but it simply would not break. It was harder even than the basalt.

"Have you found the answer to your question yet?" asked the doctor.

"No! how can I."

"Well just go on hammering until you do."

Ronald, feeling very hot and cross, turned and looked at him. "Do you think now," said his friend, smiling, "that anything else than fire can have made that piece of sandstone so terribly hard?"

"No!" said the boy as he picked up a splinter. "I can see this has been well baked. It is as hard as flint."

"Yes! the heat has changed the sandstone into quartzite. When the volcano burst its way to the surface, it smashed all the rocks above it, and blew their fragments into the air. Small bits might be thrown half a mile, but these big chunks were too much even for a volcano. They went up into the air and fell right down again into the mass of boiling cinders round the 'neck' they had come out of. You can always find out where the throat of an old volcano has been by watching the sizes of these included blocks. The smallest will have travelled furthest and are found at the outside of the circle. Then they get larger and

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larger as you approach the centre, or "neck," they have been shot out of."

"How can you prove that the red sandstone was formed in the bottom of a lake, and that volcanoes burst up through it?"

"That is a difficult question to answer, Ronald, and I think you will understand it better if we go and examine the Old Red rocks again."

"How is it, doctor," said Ronald, as they walked round the ruin of the old castle, "that some of these stones seem to decay so much more quickly than the others."

"When a rock is being broken up by the action of the weather, it is the rain that dissolves out again the cementing substances between the sand grains, and allows them to fall apart from one another."

"The 'weathering' of the rocks is a chemical rather than a mechanical process."

"There are two ways in which I could destroy that old castle wall yonder. I might bring a battering ram and smash it by brute force, or I might quietly pick out all the mortar between the stones, and then it would soon fall to pieces. The sun and the wind and the frost act mechanically like the battering ram, but the real rock destroyer is the rain. It is not the hammer of Thor the Earth-shaker, but the deadly kiss

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of the dewdrop that lays the mountain in the dust.

“By its chemical action the rain, armed with millions of particles of carbonic acid gas which it has absorbed as it came through the air, slowly and silently unbuilds the mountains. By its mechanical action the rain lifts the dismembered remains of the mountain and carries them into the depths of the sea.

“A particle of rain can never be killed, it never stops working, it never gets tired, it can never forget that it must destroy rocks. Falling through the sky it captures carbonic acid gas from the air, and becomes a biting acid. It can pass through the smallest chink in the armour of the hills. It discovers every joint in the rocks, and it enters the tiniest crevice. There is no substance in the world that is not to some extent dissolved by water. No particle of water ever returns to the sea empty handed. Whenever it feels the call of the sun it is ready to soar into the air, arm itself again and make a new attack upon the rocks.

“There is no beginning and no end of the life of a grain of sand. Every particle at your feet may be far older than the oldest mountain you know. If you look at a single grain of sand through a magnifying glass, you will see it is part of a crystal of quartz, so small and so hard that it

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is difficult to break it into anything smaller. The entire life history of any water-formed rock is soon told, even though it may have existed for twenty million years, like the one we are sitting on. It begins and ends in grains of sand, but the same grain of sand may form a part of many successive rocks. In the beginning there was an old rock crumbling to pieces under the action of the weather. The rain washed these sand grains into the river, and the river raced down with them to the sea. Then its current grew slower and slower. It could no longer carry the sand grains, so it dropped them, and they fell to the bottom and lay for ages one on the top of the other.

“Three things were needed to change this heap of loose sand into sandstone—pressure, heat, and an adhesive substance. As layer after layer of new sand was brought down by the river, the heap grew higher and heavier till there was a tremendous weight of sand resting upon the bottom layers of the pile.

“All the time the heap was growing, water was trickling through it, filling up the spaces between the grains and fastening them together with the lime it had dissolved out of the shells and bones of small animals which had also fallen to the bottom of the sea.

“The rock-paste was now all mixed and ready

Dunbar Castle

for baking—but where was the fire? and where was the oven?

“The fire was the original internal heat of the earth. As layer after layer of sand was piled up each layer acted like a huge blanket and helped to keep the internal heat from escaping.

“When these blanket layers had become about two miles thick, the heat in the lowest part of the pile would be sufficient to boil water, and the pressure of the immense weight of sand lying upon it would be enormous. In this way the original grains of sand were cemented, pressed, and baked into hard rock. They did not, however, lose their identity, and now, after millions of years, as the rocks lying above them have been raised to the surface of the earth, and gradually eaten away, the same old grains of sand are now lying here with their cementing substances partially dissolved away.

“Let us take this old nail and scrape a few of them off the top of the rock, and drop them into the sea to begin another stage of their journey.”

Here the doctor, who had been poking in the ground with the point of his stick, stooped down and picked out a rusty nail with a lot of sand clinging to it.

“This is an example of another way in which the particles of sandstone may be cemented together. This bundle of sand and small pieces of gravel

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clustered round the old nail is nearly as hard as stone, because after the rain had dissolved off small quantities of the iron rust from the nail, it soaked through the sand around it, and left some of the iron behind, which acted as a cement and caused the grains of sand to stick to one another.

Chapter the Seventeenth

DUNBAR—II

Classification of Rocks



HOW can you show me that these tremendous changes have really taken place since this old Red Rock was formed," said Ronald. "I see no signs of your volcanoes."

"Wait till we get back to the castle and I shall prove it by showing you that the same forces are acting now, that have been acting throughout millions of years, and that they can and do produce the same results to-day.

"You told me quite correctly that the harbour wall had been built up by some one, stone by stone, because you had seen walls built in other places.

"In the same way these sandstone rocks have been built up grain by grain, and the separate grains have been cemented together just as the stones in the wall have been joined with mortar.

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“The total thickness of the whole series of sedimentary rocks as now measured by geologists is thirty miles. They have been built up of tiny grains brought down by the rivers and piled one above another, and the time it has taken to build them is at least one hundred millions of years.

“All the rocks of the world have now been classified into five great divisions, they are numbered: 0, 1, 2, 3, 4, and named Archæan or Pre-Cambrian, Primary, Secondary, Tertiary, and Quaternary. Early geologists divided all the rocks into three kinds. The first they called Primary or Palæozoic, from two Greek words—*palaios*, meaning ancient, and *zoé*, life; the second they called Secondary or Mesozoic, or middle life; and the third they named Tertiary or Cainozoic, meaning recent life.

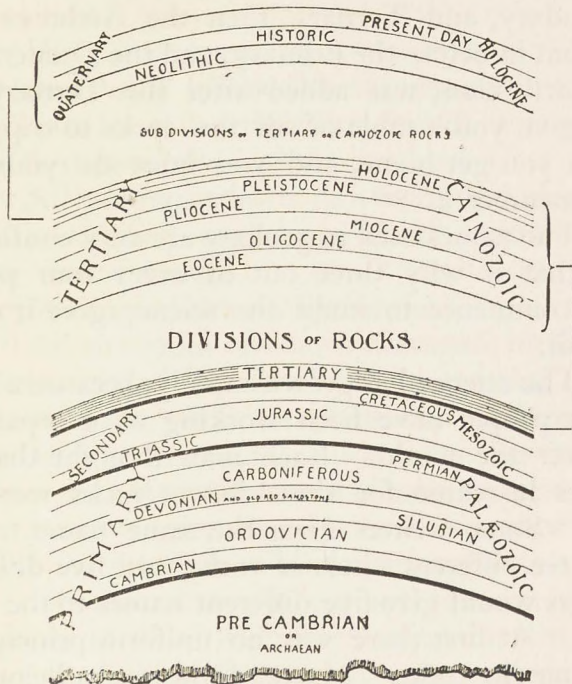
“It was not long, however, before they discovered that there were rocks far older than those they already had named Primary—so they called these still older rocks the “Archæan,” from a Greek word meaning “beginning.” These Archæan series are the oldest rocks and contain no recognisable trace of life, and may be considered as the foundation rocks on which all the others have been laid down. When men of science began to calculate the ages of the various rocks they found

Classification of Rocks

that the Tertiary rocks were at least three millions of years old. After these, come a whole series of

CLASSIFICATION OF ROCKS.

SUB-DIVISIONS HOLOCENE OR QUATERNARY ROCKS.



later rocks, far more important to us than all the rest put together, because they contained the remains of man. It was, therefore, decided to restrict the

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old name Tertiary to the rocks which were laid down before man appeared on the earth, and to call all the rocks which have been formed since then Post-Tertiary or Quaternary.

“There were first three divisions—Primary, Secondary, and Tertiary, then the Archæan class was put in before the Primary, and the Quaternary, or fourth class, was added after the Tertiary. I will give you a table of all the rocks to copy out when you get home, and you must do your best to remember it.

“The names used in geology are very confusing, and that is why three out of every four people who commence to study the science give it up in despair.

“The science has grown rapidly, because a great many people have been working at it separately all over the world. Each man thought that the names he chose for the different rocks were the best. Some writers gave the same name to two or three different kinds of rocks, and five different writers would give five different names to the same rock. At first there was no uniform principle of naming the rocks. Many of the rocks belonging to the Old Red Sandstone formation, for instance, are not red, and are not sandstone, and would not now be named “Old.” Indeed, this period in Scotland was characterised not by its sandstone,

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but by its great lakes and tremendous volcanic activity.

"Cambrian rocks are found not only in Wales, where these rocks were first studied and named, but in China and in the Argentine and, in fact, all over the world."

"Well, doctor, on what principle are the rocks named now, if it's not the kinds of stone, or the countries in which they are found, or the way in which they were made?"

"All geologists have now agreed to classify the rocks according to the geological period in which they were formed.

"Geological time is fossil time.

"All the rocks are now arranged in the order of creation of the fossils they contain, that is, in accordance with the particular fossils that first appeared on the earth during the age in which these particular rocks were being formed.

"I want you, Ronald, to thoroughly understand the principle of these geological names.

"The name is not applied to any particular rock, or kind of rock, or method in which rocks came into existence, but to a whole series of rocks formed during the lifetime of a group of fossils.

"The particular name was given originally to a particular group of rocks, either because of the most characteristic kind of rock in the group, or

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because of the particular country or locality in which that group of rocks was first discovered or described.

“Now this name has been taken away from the group of rocks it was at first given to, and applied to the period of geological (that is fossil) time, during which that group of rocks were laid down.

“We speak of a ‘Norman church,’ an ‘Elizabethan drama,’ ‘Queen Anne furniture,’ or ‘early Victorian costumes,’ not because the church is in Normandy, or was actually built by Normans, but because it was built in the style of architecture that was introduced during the time the Normans dominated England.

“Similarly we do not mean that Queen Elizabeth wrote the drama, or that Queen Anne made or used the furniture, or that Queen Victoria wore that kind of costume in the early years of her reign, but we mean that that kind of drama, or furniture, or costume, was characteristic of the period.

“In the same way ‘an Old Red Sandstone’ volcano doesn’t mean a volcano made of old red sandstone or one which erupted old red sandstone materials, but a volcano that was in eruption during Old Red Sandstone time. Cambrian rocks mean rocks belonging to the geological period during

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which the old rocks in Wales were formed. This is clear from the fact that the same dominant fossils are found in all these rocks.

“Before the Union of the Crowns, England and Scotland were ruled by separate kings reigning at the same time, and the countries were called by different names, yet the people of the two countries were really descendants of the same great races, and had reached about the same stage of civilisation. In the same way the Devonian rocks of England were being formed at the same time as the Old Red Sandstone rocks of Scotland.

“Supposing a skeleton were dug up from the field of the Battle of Bannockburn, you could not tell by examining the bones alone, whether it was a fossil Englishman or a fossil Scotchman. If, however, part of his armour or clothing or equipment happened to be preserved, you might be able to tell from these which nation he belonged to.

“The Devonian rocks of England contain the remains of salt water animals, and must therefore have been laid down in the sea, while the Old Red Sandstones contain the fossils of fresh water animals.

“We conclude, therefore, that during the period in which both these sets of animals were living on separate parts of the earth at the same time, a

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ridge of hills had risen above the bed of the sea. This ridge created an inland lake by cutting Scotland and the land now lying under the North Sea off from the main ocean, in which the Devonian rocks were being laid down. The great rivers of Europe flowing into this shallow inland sea, or great lake, kept its water fresh, while the water on the other side of the ridge was salt, and sea animals lived on the outside, and fresh water animals lived on the inside of the ridge.

“The geological succession of rocks has to be remembered in the same way as the succession of the kings of England. Geological periods are the reigns of groups of fossils which appeared on the earth in bygone ages, fought for supremacy, ruled, and were in their turn subdued by the higher forms of life, which followed them.

“This general arrangement of rocks extends throughout every country in the world, and they are always found in the same order. You must not, however, imagine that the earth has all these five skins of rock lying over every part of its surface, and that if we were to dig down anywhere, we should come to first, Quaternary then Tertiary, then Secondary, then Primary, and lastly Archæan rocks, and that finally if we passed through these, we should reach a liquid core.

“On the contrary, the newer rocks have been

Classification of Rocks

mostly built up out of the remains of older ones. Great areas of the older rocks had to be destroyed in order to furnish material to make the new rocks out of.

“The skin of the earth is always wobbling and shrinking and crinkling. Whenever a portion of the earth’s crust wobbled up out of the water, it was shaved off, and thrown back into the sea to be used over again in rock forming.

“During the time these exposed parts of the earth were being crumbled into grains, and carried out to sea, the inside of the earth was growing colder, and therefore smaller. The outside skin had to wobble and shrink and wrinkle to fit itself again to the inside core, and thus a new set of continents was made, for a new family of rivers to devour.

“When we find Quaternary or Post-Tertiary rocks in any part of the country, it is probable that Tertiary, Secondary, Primary, and Archæan rocks are lying underneath, but wherever the Archæan rocks appear on the surface we may assume that all the newer rocks, which once covered them, have been washed away, and that we may be standing on the old skin of the molten earth.

“The rock crust which covers the earth is hard and brittle. When it has to adjust itself to internal changes, it not only wobbles and wrinkles, but it often cracks. Then the molten rock inside, sub-

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jected to terrific heat and pressure of its imprisoned gases and the tremendous weight of miles of rock pressing down upon it, finds out the crack, bursts up through it, and flows over the surface of the earth. In some parts of the world these outflows of lava are hundreds of feet thick and cover thousands of miles of country. They overlie and

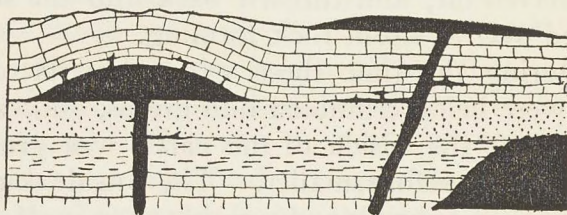


Diagram to represent the relation of Igneous Rocks to Stratified Rock. The Igneous Rocks (black) have been forced up from beneath.—(After Gilbert.)

are sandwiched in between all the different varieties of sedimentary rocks.

“The white hot liquid inside the earth is always endeavouring to spout up through its crust. When it reaches the surface it flows out in the form of lava and cools rapidly. Sometimes, however, the crack does not open right up to the surface, or else the melted lava when it gets up into the cold rocks near the top of the crack, cools, sets solid, and chokes up the crack. The stream of white-hot rock, welling up from beneath, finding the trap door

Classification of Rocks

shut down upon it, spreads to right and left under the floor, forces great areas of stratified rocks out of their beds, and flows underneath them and floats them up, just as rising water in a well or cellar will float up planks of wood which were originally lying upon the bottom of it.



Sill of Basalt (or Granite).

“When the melted rock succeeds in reaching the surface and pouring itself out, it cools very rapidly and is called lava. When it forces its way in beneath some other set of rocks, it is called an intrusive sill.

“If the crack is a large one, or if the mass of white-hot rock keeps pouring up, till it has melted out for itself a big round hole in the rocks it has come through, it becomes a “vent” or permanent chimney for the fires of the underworld, and if it continues spouting up rubbish enough to make a conical hill all round it, it is called a volcano.”

BASS ROCK

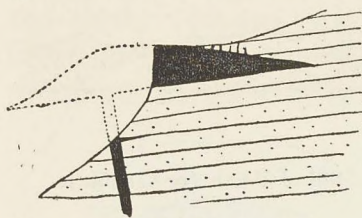
Ronald and the doctor were sitting on the top of the cliffs watching the great waves rolling in from the North Sea.

“Can you tell me, doctor, how the Bass Rock

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comes to be out there, standing all by itself in the middle of the Firth?"

"The Bass Rock, Ronald, is a solid plug of igneous rock which now fills the hole in the



earth through which melted lava at one time poured up, and flowed over the surrounding country. Now it is left like the stalk of a mush-

Diagram of a Sill showing its former room from which the head has been removed.
extension as a Laccolite.

"Originally the whole mass of rock was shaped like a gigantic mushroom. The stem was the hole in the ground through which the melted rock had surged up, and the head of the mushroom was the lava, which had flowed out over the surface of the earth before cooling. You may see something like this on a very small scale, in a paved street where the square paving stones have been fixed with pitch. In hot weather the pitch is heated by the sun and oozes up from between the paving stones, and forms on the surface into little black balls or cakes.

"Long ages ago, when the cold crust of the earth was much thinner than it is now, the mass of boiling rock inside, crushed down by the tremendous weight of solid earth lying on top of

Classification of Rocks

it, found a crack in the shell through which it could spout up. You have often seen an egg, with a little crack in its side, put into a pan to boil. You did not know the crack was there, but when the egg became heated the liquid inside the shell wanted



Ideal cross section of a Laccolite.

to expand, as everything must expand when it is heated, so it pressed all round and round the inside of the shell, until it found the place weakened by the crack. It forced itself through the crack, and solidified when it came into contact with the boiling water outside.

“This was what happened on a much larger scale when the Bass Rock came out of the inside of the earth, which at that part of Scotland was then thousands of feet higher than it now is. The earth was a ball of hot liquid with a shell of rock surrounded by a mass of air, just as the boiling egg in the pan is surrounded by a mass of water. The melted rock was squeezed through the crack in the softer rocks above it, and as the lava passed through the hole, being intensely hot itself, it melted the rocks it was pouring through, and made the hole bigger and bigger, like a hot

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poker being pushed through a sheet of ice. When the melted rock reached the outside of the earth's shell it became solid and spread out like the white of egg that has boiled through the crack.

"All the mass of rock that formed the head of the mushroom of cold lava (so to speak) has been ground down by the rivers and glaciers which carved out the valley now filled by the Firth of Forth. The river flowing over the softer rocks through which the boiling basalt rock had poured up, gradually washed them away. The plug of cold basalt was very much harder than the surrounding rocks, which in the succeeding ages the river has worn away grain by grain and carried out into the sea. This is the long story of which the Bass Rock stands to-day a silent witness.

"Stirling Castle Hill is another basalt sill or sheet, and the River Forth has washed away the softer rock which once enveloped it.

"The tide still runs up to Stirling and steamers sail regularly past the foot of the castle crag. If the sea rose 200 feet they could sail right across to Glasgow and the Atlantic ocean. Stirling Castle would then be standing in the middle of the sea, as the Bass Rock is to-day.

"Edinburgh Castle is also the lower part of the stem of a mushroom of molten basalt lava which

Classification of Rocks

was forced up into the layers of sandstone lying above it. It stood in the track of the glaciers that widened out the valley of Firth of Forth. The glaciers soon wore away the sandstone round about the stalk of the mushroom, and then this fell down bit by bit into the river of ice flowing on each side of it and was carried away out to sea.

"The castle rock still bears many scratches and other marks of its long struggle with the glaciers. What interests us still more is the fact that we are able accurately to calculate the rate at which, even in our quiet and peaceful times, Edinburgh Castle rock is being wasted away by the action of sun and rain. Owing to the fact that it is surrounded on all sides by public roads the War Office employs a contractor to regularly remove all the pieces of rock that fall or seem likely to fall. For a number of years the amount of rock so removed has averaged about one ton a week, or fifty tons a year.

"At this rate about 8000 tons must have fallen from the rock since 1745 when Prince Charlie marched up with his army and summoned the castle to surrender to him.

"Dunbar Castle here is built on the plug of an old volcano."

Bill, who had heard the lecture before and was becoming hungry, now said that he was tired of carrying the basket about, and suggested that

Secrets of the Hills

they should eat their lunch, for the wind had grown so strong that they evidently could not go out in a boat that day.

Bill divided the lunch, and handed his father a plate with a ham sandwich, a brown bread and water-cress sandwich, and an egg sandwich lying on top of each other.

"This," said the doctor, "is an ideal lunch for a geologist. It makes a good model of a section of the earth's crust. You see the different strata. The plate represents the Archæan foundation rocks with no signs of life in it. The ham sandwich is——"

"Fossil pig between two layers of sandstone," broke in Bill.

"You'd better not let cook hear you say that," rejoined Lizzie.

"No," said the doctor; "the ham sandwich consists of vegetable and animal remains considerably altered by heat and chemical action, so that their origin is not at first apparent; it represents the Cambrian, Silurian and Ordovician series of rocks with their volcanic intrusions.

"The brown bread and water-cress sandwich interests us most. Here we see the coal measures lying above the Old and below the new Red Sandstones. This is our great geological landmark. The working of these beds of coal and iron has made the British Empire. The only question a

Classification of Rocks

practical business man ever asks a geologist is, 'Is there any coal or iron or limestone under the ground here?' However little you know, people will consider you an authority, if you can tell them whether their land is situated in, above, or below the Carboniferous series.

"You should always be able to find out where you stand in relation to the great carboniferous sandwich. If you are amongst Permian or New Red Sandstone rocks the coal measures may be beneath you, but probably too far down to be worked at a profit. While if you find that the rocks about you belong to the Old Red Sandstone period, you know that the coal seams have been washed off that part of the earth millions of years ago.

"We need not trouble ourselves much about the other series. The egg sandwich may stand for the Secondary and the Tertiary periods.

"Bill can go to the ice-cream man yonder, and procure a glacier resting on a layer of boulder clay, and covered by a deposit of river gravel, while I shall content myself with a biscuit and some gorgonzola cheese, to represent the post-glacial strata, and presently existing life."

"Cheese mites?" interrupted Bill.

"This will be geologically accurate," continued the doctor severely, "as there were not glaciers in

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all parts of the country, and I prefer to remain an unglaciated part of the surface.

"You will learn more geology in an afternoon by climbing to a hill top and studying the surrounding country with the aid of a good geological map, than by reading geology books for a whole month.

"Now," said the doctor, "I think the tide is far enough out for us to examine the rocks at the foot of the castle cliffs. You will see the place where the old volcano has forced its neck or chimney up through the overlying beds of the Old Red Sandstone. Then we shall note how the neck has itself been filled up by volcanic agglomerate. And, lastly, we shall trace the intrusive masses of basalt rock, which have forced their way up into the Old Red Sandstone beds and volcanic agglomerate alike, and sent out fiery tongues which have melted their way into the overlying rocks, far in advance of the main body of the intrusion.

"After dinner I'll show you on the geological map (page 80) where the rocks we find here crop up in Fife on the other side of the Forth; and explain how we can prove that once they extended across the present sea and were covered by 10,000 feet of newer rocks, which have now been washed away."

Chapter the Eighteenth

The Work of the Sea

*Bubbling, boiling, hissing and seething,
As when water with fire doeth vie,
Exhausted never and ceasing not,
The new wave by the old is begot.*

SCHILLER



OW is it, doctor, that if the waves can break away the sandstone cliffs they do not break away the harbour wall? I do not see how water merely splashing up against rocks can destroy them. The water doesn't hurt anything, it just flows up and falls down again."

"It is quite true, Ronald, that water is soft and yielding. By itself, it would be a long, long time in wearing away the rocks, but the wave at the foot of the cliff is armed with loose stones, just as the velvety paw of a cat is armed with claws.

"If you wanted to break a stone which you had found on the seashore, and had no hammer, what would you do?"

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"I should get a big stone and let it fall on the other one."

"That is what the sea is doing all day and all night."

"If you made up your mind, Ronald, to smash a rock, and worked away with all your strength for three or four hours, I have no doubt you would make some impression on it."

"Now what, exactly, would you be doing? You would lift a stone weighing, say twenty pounds, three feet high, and let it fall on the stone you wished to break. The force you would be using would be measured by the weight you lifted, and the height through which it fell. A boy on the seashore would at least leave his mark on the rock if he hit it often enough."

"The sea in a storm can lift a block of rock weighing twenty tons, not only three feet, but even thirty feet high, and hurl it against the side of the cliff, with tremendous force. Compare your strength with the might of the sea, or compare the few minutes you could keep on lifting the stone with the everlasting work of the sea, and you will understand how the cliffs are broken away."

"How many miles do you think these stones at our feet have travelled, Ronald?"

The Work of the Sea

"Nobody could possibly answer that question, doctor. These stones may have come from the Highland hills a hundred miles away."

"That may be true of some of them Ronald; but it is not of those stones I am thinking. I meant these round red stones, which have evidently fallen from the cliff above us."

"Why, doctor, they haven't travelled at all. They are not twenty yards from the place where they first fell, though they may have rolled backward and forward a little."

"These stones, Ronald, have travelled over a thousand miles since I looked at them this time last year."

"Surely, doctor, that is impossible."

"Well, Ronald, just watch any one of them for a minute, and see how far it travels each time a wave rolls up the beach and back again."

"Well, I daresay, the stone travels about two yards each way."

"Suppose, however, that it only rolls one yard up and down each time the wave catches it. Count now the number of waves in a minute, Ronald."

"There are about ten."

"If every wave rolls the stone one yard up, and one yard down, that is, two yards; and if there are ten waves a minute, the stone will roll twenty yards each minute, that is 1200 yards, or two-thirds

Secrets of the Hills

of a mile each hour. If the waves were always rolling over this part of the beach, that would give sixteen miles a day, and if you multiply sixteen by 365, you will find that the stone travels 6000 miles every year, or fourteen times the distance from Dunbar to London. If you were to take one of these stones, Ronald, and roll it over the 400 miles of road from here to London and the 400 miles back again, seven times, don't you think the corners would be pretty well knocked off?"

"I think, doctor, the sandstone would be all worn away to bits long before I rolled it to London."

"How much other work do you think you could do in a year, Ronald, if you had to roll that stone from here to London and back seven times?"

"Oh, plenty! It wouldn't take me all the time to do that!"

"How long a holiday do you think you would get at the end of the year? Suppose you rolled that stone steadily fifteen miles along the London Road every day, how long would it take you to cover the 400 miles?"

Ronald worked it out at twenty-six days.

"You would like a week's rest when you got to London?"

"Well, I daresay, doctor!"

"Then it would take you another month to roll the stone back again."



Photo the late Mr. Foxe Strangeways

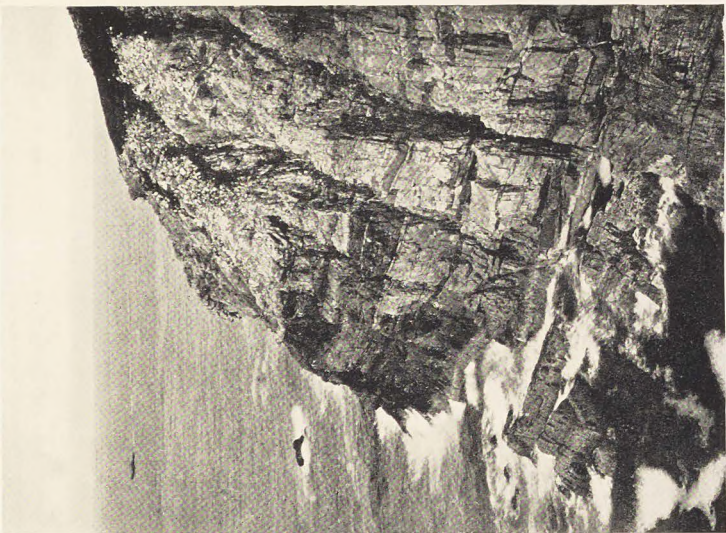


Photo Geological Survey

1. First Doodle, near Filey, Yorks. 2. Cape Wrath. At Filey the sea rapidly undermines the cliffs by washing out the concretions and hurling them with great force back at the parent rocks. At Cape Wrath the crystalline rocks are so hard that the sea makes little impression upon them. The air with its chemical action is here the great destroying force, as is shown by the backward slope of the cliffs.



The Work of the Sea

"Yes, doctor."

"That is fourteen months for the seven double journeys."

"Yes, doctor."

"Well, Ronald, how many holidays would you have in that year?"

Ronald was silent a while.

"Oh, doctor! I never thought it took so much work to round the corners of a stone on the sea-shore."

"Geology, Ronald, takes a lot of thinking. There is no beach, however, where the stones are rolled up and down by the tide for the full twenty-four hours, but I am quite safe in saying that these stones have travelled a thousand miles since they fell from the cliff."

"I understand now, doctor, how the rocks get ground away to sand, once they fall down on to the shore, but they are all right as long as they are in the cliff."

"What would happen to a tall tree if you cut it through at the root?"

"Why, of course, the tree would fall with a crash."

"That is just what happens with the cliff, Ronald, when the sea has cut into its base. The part which has been undermined breaks off from the rest of the cliff and falls into the sea."

"If you wanted to knock a hole in the side of

Secrets of the Hills

the cliff, you would take a small stone and hammer the cliff with it. The same blow is struck, whether the stone is held in your hand, and, moved by the strength of your arm, or whether it is lifted up in the bosom of the wave and struck against the cliff.

“This morning I saw you polishing a rusty golf club. If you had simply rubbed the rusty iron with a piece of cloth, you would not have produced much effect on it.

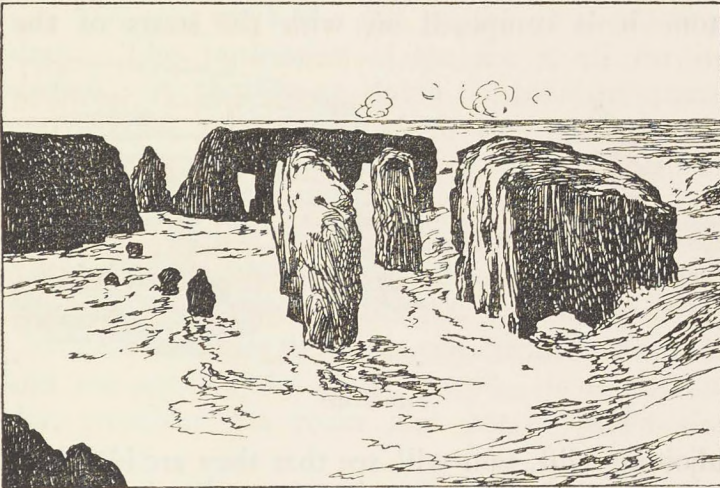
“When you put sand on the cloth and rubbed the rusty iron with the sand, you soon scratched off the rust, and even removed some of the iron itself. In wearing away the cliffs, the waves act like the cloth, and the gravel and stones like the sand with which you cleaned the golf club.

“The sea has been compared to a great horizontal steam saw constantly cutting into the land all round the coast, sawing off all the cliffs and small hills, and leaving a wide flat plain, over which it rolls forever.

“The broken pieces of rock will lie at the foot of the cliff, and the sea will use them as hammers to strike the remaining rocks with, till a fresh piece of the cliff has been undermined and falls down in its turn. Every piece of rock that drops into the sea becomes a battering ram continually being swung by the waves against the parent cliff.

The Work of the Sea

"In these cliffs are great cracks running inland. The waves are constantly dashing into these cracks, widening them into small creeks. The stones and broken rocks which fall from the cliffs can never get out of the creeks, but are kept con-

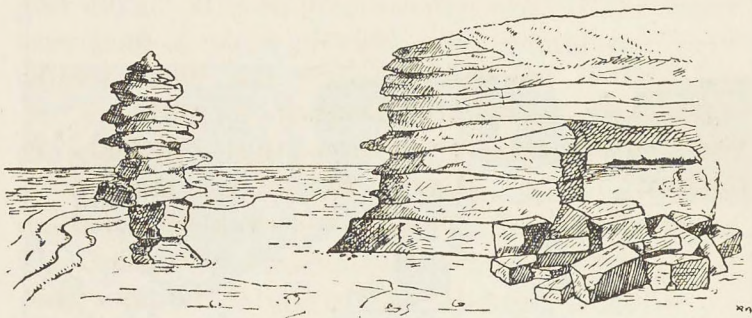


"Stacks," hard parts of the cliffs left standing after the softer parts have been washed away.

tinually rolling backward and forward, always grinding away at the base of the cliffs. This picture shows where the cracks have become wider and wider till the whole cliff has been worn away and only narrow pillars of rock are left to show where the cliff stood not so long ago.

Secrets of the Hills

"I have a sketch of a very interesting rock pillar about twelve miles east of this, which the fishermen used to call Standalane. At first sight you would say it was impossible that this fantastically shaped monument could be the work of the waves, but if you compare the strata of the sandstone it is composed of, with the strata of the



Standalane

adjoining cliff, you will see that they are identical. It is the same waves that have cut the arch-way through the cliff, and in a few years the roof of the arch will fall, leaving quite as fantastic a stack as old Standalane himself, which in its turn will be undermined by the sea into which it will finally topple over.

"In striking contrast to the rock breaking might and fury of the sea, is its helplessness without its teeth. Deprived of its sand and gravel the sea

The Work of the Sea

cannot even scratch the rocks. The bosom of the deep is the quietest and most restful place imaginable. It is the great world-wide museum in which nearly all our geological specimens have been preserved. Immediately you get below the shallow surface layer, which is constantly disturbed by the tides, you reach the still depths of everlasting sleep. The restlessness of the sea is all on its surface. A short way down is constant peace and eternal repose, in which the most fragile organisms can rest undisturbed for millions of years, until each of their separate particles is replaced by a particle of stone, and they become fossils, the monuments of a long passed world, of which every other trace has vanished.

"The sea is not the destroyer, but the rest-giver and recreator of the whole world. It is the air that crumbles the rocks and breaks down the mountains.

"Up the Forth there, at Rosyth Castle, I can show you at low tide, glacier scratches on the rocks going right down into deep water, as clear cut to-day, as when they were first made; though the tide has been washing over them for the thousands and thousands of years, since the glaciers disappeared from this country.

"The rocks at Loch Coruisk show some of the finest glacier scratchings I know, because the

Secrets of the Hills

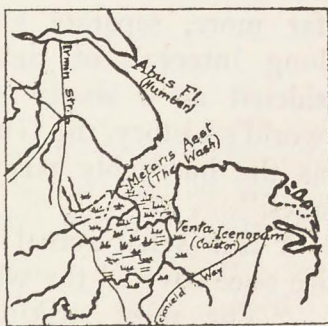
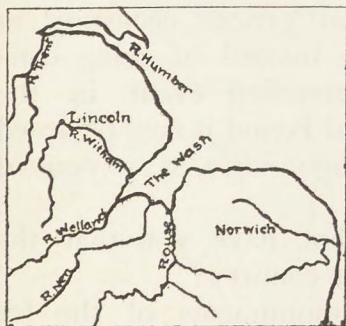
scratches have been preserved from the frost by the sea water. All the sediment brought down by the streams is left in the depths of the loch in the rock basin carved out by the glacier, and the clear water flows harmlessly over the lip of the basin into the sea. The Niagara Falls are a striking example of the feebleness of unarmed water. The falls could not continue to exist except for the fact, that all the gravel and sand brought down by the St Lawrence River system from its upper reaches, is dropped to the bottom of the lakes it passes through. In spite of its immense volume the Niagara River is soft and powerless, and cannot cut a gradually deepening channel for itself, like every other river does, and as it would do, if it had not been deprived of all its cutting tools. Flowing along the top of the rocks it cannot cut into, the river falls helplessly over their edge. Then it astonishes the world by this display of its gigantic power, while it is in reality a display of its weakness.

“The work of the rivers and of the sea is well illustrated in the recent Report of the Royal Commission on Coast Erosion. It has been found that during the last thirty-five years about 6640 acres have been lost to the United Kingdom, while over 48,000 acres have been added. The gains are almost entirely in the tidal estuaries, which

The Work of the Sea

are being continuously filled up by the rivers with sand and gravel brought down from the land. When you remember that every square foot of the 48,000 acres represents the top of a long sloping pile of sand which has been built up from the sea bottom, and that by far the greater part of the material brought down by the rivers is carried right away into deep water; you will realise how many millions of tons of soil must have been robbed from the land during this short period.

“In some places banks of shingle, formed by the breaking down of the cliffs, have barred back the sea, but there is very little evidence to prove that land once taken away by the sea is ever restored. The Goodwin Sands, so dreaded by sailors, were still dry land when Dunbar Castle was being built in the eleventh century, and the two maps below show the extent to which ‘The Wash’ has been filled up since that time.”



Chapter the Nineteenth

When the world was smothered in ice—Glaciers



OW can you prove what you told us last night, doctor, that this country was once covered by a great ice sheet three thousand feet thick; and that the mountain sides were carved, and the valleys scooped out by the glaciers?"

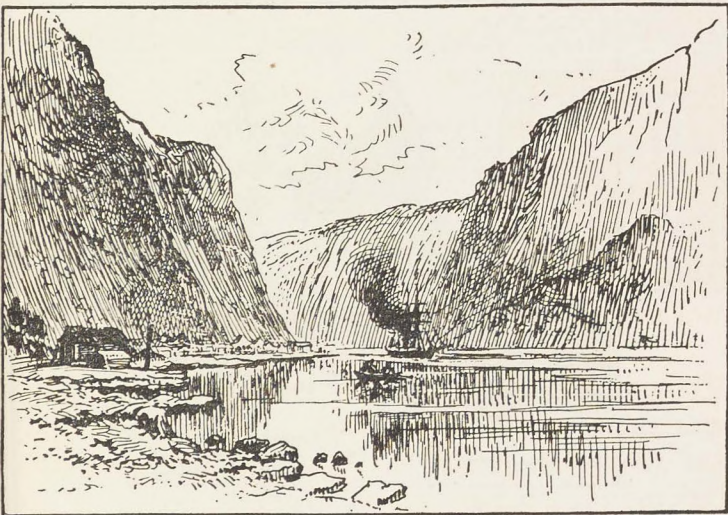
"There is abundant proof all round you, Ronald, and geologists now know that, not only was there one glacial period 150,000 years ago, but that there were certainly four, and probably far more, separate glacial periods occurring at long intervals of time. Instead of being considered as a single outstanding event in the world's history, the Glacial Period is now regarded as the inevitably recurring winter of a year of ages."

"But what actual proof have you that the ice once covered the whole country?"

"The most striking monuments of the Ice

Glaciers

Age are the great boulders, often many tons in weight, scattered all over the country. They are composed of stone quite different from any of the rocks in their locality. They are lying loose on the ground, sometimes resting on the

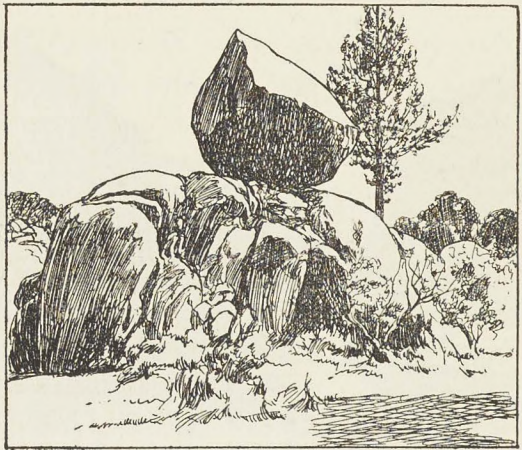


Norwegian Fjord.—Note how the V-shaped river valley has been widened by glaciers to the U-shaped fjord.

top of other rocks, and not infrequently perched on the brow of a hill, in such a position that a slight push would send them rolling down the slope. Evidently they don't belong to the place, and haven't been there very long. Where did they come from? They couldn't be explained

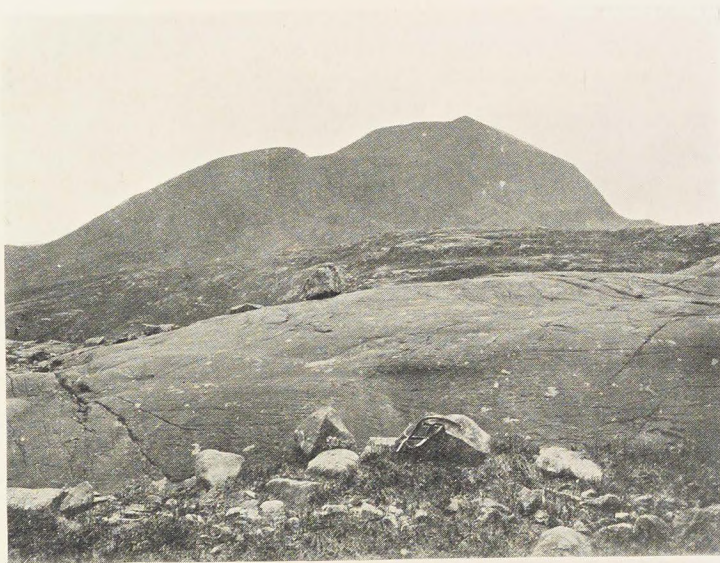
Secrets of the Hills

away. They stood there staring men in the face and demanding an answer to this question. There was no conceivable reason for their being where they were. They could serve no human purpose, and were too big to be moved by any human hand. They must therefore have been put there



A Boulder left by a Glacier.

by the gods. As there was still no reason why the gods should have put them there, man was driven back upon the explanation that the gods must have had a fight, and flung the boulders at one another. The beaten gods ran off and the victorious gods chased them, and left the stones lying. But that suggested a further question,



Photos R. Lunn, Geological Survey

1. Rock surface worn by glaciers, with perched blocks left at the sides.
2. Glacier basin at the foot of Blaven, near Loch Cornish, Skye.



Glaciers

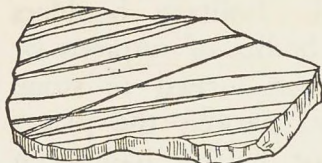
‘Where did the gods get the big stones from?’ After the rock-throwing gods grew out of fashion, the boulders were attributed to giants who were going to build walls and quarrelled, or witches who were preparing to dam up rivers, when something broke their spell. Solitary boulders were said to represent the bodies of impious or reckless mortals who had been turned to stone by higher powers, or they marked the places where kings were buried, or battles had been fought.

“The worst of it was there were too many boulders. Gods couldn’t have been fighting, or kings buried, or witches building dams everywhere. So for hundreds of years the boulders lay there, each asking ‘Where did I come from?’ Travellers who saw the boulders said the same rocks were found in mountains fifty, or a hundred, or in some cases a thousand miles away. Samples of these parent rocks were brought and compared with the boulders, and they were seen to be the same. But how had they been carried all that distance? Rivers can roll along fairly large stones but not huge blocks like these, and certainly rivers could never have carried them on to the hill tops.

“The boulders were rounded and polished, and covered with long deep scratches. The scratches

Secrets of the Hills

were all drawn in the same direction. They must have been caused either by a sharp cornered rock being dragged across the boulder, or by the boulders being pushed along the top of a sharp pointed rock. The scratches on a dozen, then on



Rock Surfaces scratched by
Glaciers.

a hundred scattered blocks were examined. They all pointed the same way. Wherever the native rocks jutted out of the ground they were covered with

grooves running in the same direction as those on the boulders. Across miles and miles of country the scratches all ran the same way, and pointed towards the parent mountains from which the blocks had now undoubtedly come."

"But how?"

"Agassiz, a Swiss geologist visiting Scotland, was shown some of the groovings in the hillside. He said at once. 'This is the work of a glacier.'

"'But there are no glaciers in this country.'

"'Well, I am sure those groovings must have been made by a glacier, so there must have been glaciers in this country. There used to be many glaciers in Switzerland, in places where there are none to-day, and the present glaciers were not there always, because in some of the valleys, from

Glaciers

which the glaciers are now retreating, old mine workings have been found, which must have been cut out long before the glacier crept down and covered them.'

"A number of British geologists went over to Switzerland to study the work of the ice, then



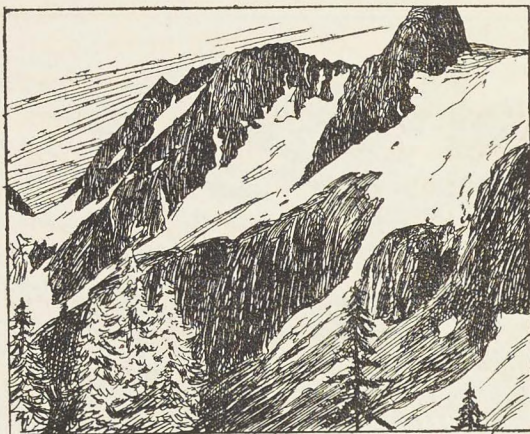
Moraine at the end of a Glacier.

examined the rock markings in their own country, and proved beyond doubt that the ice sheet extended as far south as London and was in some districts over 3000 feet thick. Almost the whole of Europe, North America, and Northern Asia were enveloped by ice during this period.

"The Boulder Clay or 'Till' which covers so

Secrets of the Hills

much of this country was undoubtedly left there by the ice sheet. It consists of ground-up rock, with many included fragments and boulders. There is no stratification, so it could not have been laid down by water, and it is certainly not volcanic. The source of its material is very plainly indicated.



Where a Glacier begins.

Its bulk is always made up of whatever rocks happen to be at the surface of the district it is found in, or of the district a little higher up and through which the ice sheet has rolled. Wherever the boulder clay is found you may be certain the ice sheet has been, in comparatively recent times, because no other agency could have produced the boulder clay.

Glaciers

"The directions of the ice scratches all over the country have been carefully noted down on maps. It is quiet easy to see the directions in which the great glaciers and ice sheets must have rolled across the country by the long trails of scratched rocks and boulders they have left behind them. In every case the flow of the ice radiated outward from the high tablelands down to the sea.

"The great cakes of boulder clay which the ice sheets left behind them completely filled up the old river valleys, while the moving mass of ice itself ground off the tops of the mountains, thus tending to obliterate the old scenery, and reduce everything to a dead level.

"When the ice had disappeared the old rivers had to begin again and carve their valleys out of the boulder clay, while many new rivers had their sources in the slowly melting glaciers.

"The Glacial Period is the great yawning gulf in time, the age of death, which cuts off the ancient world of the geologists from the living world we are in to-day."

"But, doctor, how can it ever have been cold enough for three thousand feet of ice to cover this country?"

"We must accept the evidence that lies before us, and believe the facts when we find them proved. In addition to the rock markings and the boulder

Secrets of the Hills

clay there are in this country hundreds of proofs of the existence of the Ice Age, such as the remains of animals and plants which only live in very cold countries, and in the fact that animals and plants that live in warm countries were abundant here before the ice came, and were all killed by it.

"Many fossils of fig trees and other tropical plants have been found in Greenland, which proves that it must have been once a warm country, and, on the other hand, there is evidence of several glacial periods in Africa, China, and Australia."

"But how could the climate change so much, doctor?"

"You will remember, Ronald, that, when we were talking about the Gulf Stream, or "South-West Drift," as it is now called, we saw there were a great many other factors that determined the climate of a country in addition to its position North or South of the equator. Hot and cold currents, whether of water or air, and the presence or absence of moisture and clouds, have a very much greater effect on climate than we generally suppose.

"The coming and going of the great Ice Age was probably the result of a number of separate causes acting and reacting on one another.

"The great forces of nature are so perfectly

Glaciers

balanced that we hardly know of their existence, but a slight disturbance of this adjustment may produce great results. A trifling alteration of the helm of a great battleship will bring the leviathan round in a circle till it sails in the opposite direction. A very slight change in the adjustment of the hot and cold currents in the air, and in the sea, will in time reverse the action of the weather-controlling forces, and completely change the climate of large parts of the world. Instead of the present sea-to-sky and sky-to-sea circulation of water vapour, slowly but surely carrying the land into the ocean, the process is reversed, and the oceans are slowly piled up on top of the land, in the form of snow sheets and glaciers.

“Imagine a hill country where last winter’s snow is not all melted till the end of summer. A cold summer may leave a considerable balance of unmelted snow for next winter to begin with. Year by year the balance of unmelted snow accumulates on the hill tops. This lowers the temperature, and the water vapour floating overhead is condensed and comes to the ground as a fall of snow instead of rain. Gradually the country becomes colder and colder. The snow remains in the valleys as well as on the hills, even in the summer time; and slowly but surely the snow sheet creeps down over the plains. Every

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year the water that should have run down the rivers into the sea remains on the land in the form of snow. Each succeeding snow shower adds to the weight of the overlying layers of the mass, and presses down and condenses the bottom layers into one vast sheet of ice, which soon overspreads the whole country."

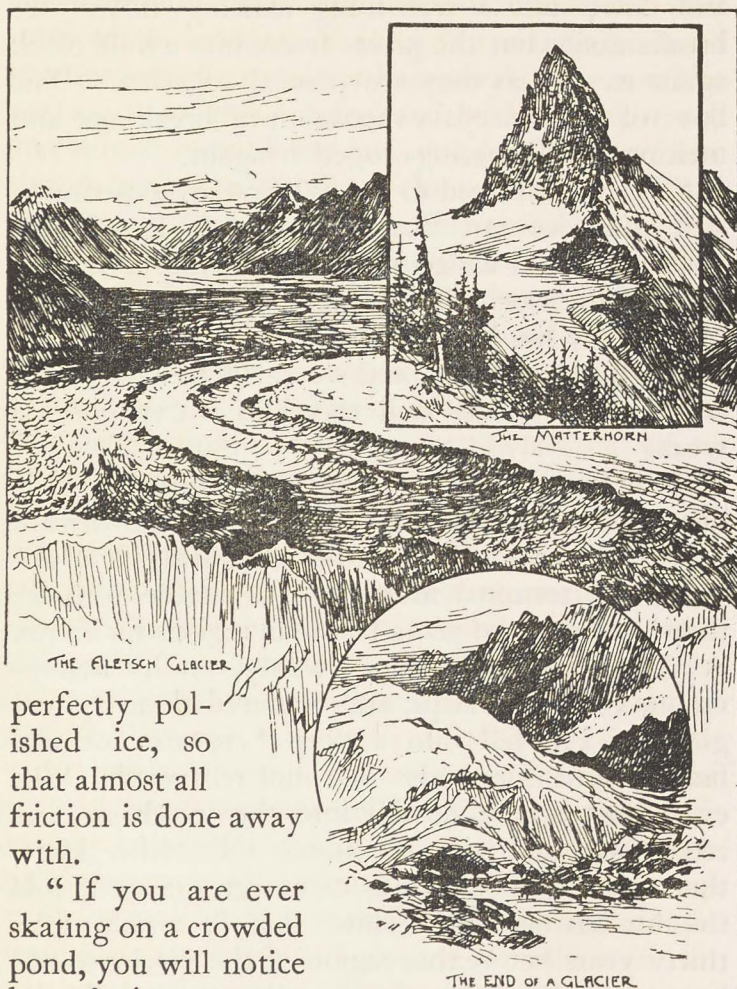
"But, doctor, how can glaciers that are made of solid ice flow along without melting?"

"Have you never seen the snow slipping down the roof of a house? Well, the snow and ice slip down the sides of the mountains into the valleys in just the same way. As more and more snow falls down and accumulates above and behind it, the mass of snow and ice in the bottom of the valley is steadily pushed downward and outward. Once it is set in motion it is kept going by the constant falls of snow in the mountains above it."

"But how can solid ice flow?"

"Ice melts under pressure, and freezes solid again the moment the pressure is released. When you glide over the ice on skates you are really sliding on water. The concentration of the weight of your body on to a skate blade less than quarter of an inch in diameter produces such an intense pressure that the ice immediately under the skate blade is melted, and forms a thin film of water between the perfectly polished steel and the

Glaciers



THE ALETSCHE GLACIER

THE MATTERHORN

THE END OF A GLACIER

perfectly polished ice, so that almost all friction is done away with.

“If you are ever skating on a crowded pond, you will notice how the ice sways up

Secrets of the Hills

and down like a well-hung dancing floor. Ice breaks easily but the pieces freeze into a solid block again as soon as they are pressed together. The flow of a glacier is a succession of breakings and meltings, and freezings together again.

“We do not need to try to prove by experiment that solid ice can flow, because we know that glaciers of solid ice actually are flowing in various parts of the world at the present moment. Their rate of flow has been accurately measured now for over a hundred years, and we can tell exactly how far a given glacier will travel in a day or in a week.

“Sir Ray Lankester narrates the following incident arising from their slow but regular downward flow to the region where they melt away and deposit, as a terminal moraine, the burden of rocks they have received years before in regions far above. A young man of five-and-twenty, on his honeymoon, visited the Alps, and ventured alone on to a glacier. He fell into a deep ‘crevasse’ or ice-fissure, and his body was not recovered. The exact spot where he fell into the ice-chasm was recognised, and the mountain folk, who knew their glacier, and its rate of movement well, told the broken-hearted widow that it would take thirty years before that region of the glacier would have moved so far downward as to reach the

Glaciers

lowest limit, and in due course melt away. She haunted the glacier in which her young husband was entombed year after year, and at last, when she was now grey-headed and withered by time, that special tract of ice had descended so far, and was so near the thawing, thinned-out margin of the glacier, that they were able to break into it with axe and pole. Then she, an old woman, had a wonderful experience. They led her to the glacier's edge. Her young husband, preserved these thirty years in the ice, which had melted around him, and re-frozen, lay there unchanged. His features were not marred by the lapse of years, nor was his clothing rent or injured. He seemed as one asleep, resting after a long day's climb, and she, poor soul, had, during a blissful interval, the conviction that all those weary years of waiting were but a long bad dream, that she, too, still was young, and was waking as she had loved to do long years ago, in time to see him lift his lids and smile."

"I think, doctor, I can quite understand how glaciers flow, and I can imagine a great rock coming tumbling down the mountain side, and falling on to a glacier, and being carried onward by the glacier until it melted, but I cannot understand how glaciers can dig out great valleys in the land they glide over. How can a glacier scoop

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out a lake bottom far below the level of the sea, as you say it has done in Loch Katrine, and then climb up a wall of rock two hundred feet high and slide down the other side of it? Water cannot flow up hill! How can ice do it? How can a glacier dig stones out of the ground and carry them on to the top of a hill?"

"Can you tell me, Ronald, why it is so hard to remove a stone that has been lying on the ice for a day or two?"

"Quite easily, doctor, because the stone gets frozen into the ice."

"Does the stone freeze, Ronald?"

"Well, no, doctor."

"Then how does it get into the ice?"

"I suppose the ice thawed and then froze again!"

"But suppose the ice didn't thaw? Sometimes the ice doesn't thaw for weeks."

"Well, I don't know *how* the stones get into the ice, but I have seen a brick sticking nearly half-way into the ice, and tried to get it out and couldn't."

"Without there being any thaw at all, Ronald, the weight of the stone pressing on the ice gradually melts a thin film of the ice it rests on, then sinking through that film, the stone melts another film and so on until it slowly presses its way through the ice. You must have often seen

Glaciers

stones and bars of iron which have become embedded in the ice in this way. When the stone has sunk down below the surface, the ice round its sides often holds it up for a time and prevents it from sinking right through.

"Now, Ronald, if its own weight of a few pounds can press the stone down into the ice; what would happen if a cake of ice were lying on top of the stone when the stone is resting on a rock?"

"I suppose that the weight of the block of ice pressing itself down on top of the stone would cause the stone to bore its way up into the ice."

"Now, suppose the first stone was resting on top of a second stone, what would happen after the first stone had been pressed up into the bottom of the glacier?"

"Why, the second stone would be pressed up into the glacier too."

"And gravel and small stones?"

"They would be pressed in too!"

"Yes, everything that the glacier rested on would be pressed up into its body. What, then, would the bottom of the glacier be like, Ronald, if you could turn it upside down?"

"Why, I suppose it would be like a patchwork quilt made of rocks."

"That is a very good description of it, Ronald.

Secrets of the Hills

The bodies of all the loose rocks would be pressed up into the body of the glacier and held in position there. The fragments of rocks themselves would have a certain power of moving about inside the ice. If their front edges caught against anything, the rocks in the glacier would either dig down into the obstruction or would be turned over by it.

“Imagine a string of gigantic beads of all sizes from six inches to twenty feet in diameter. Imagine them strung higgledy piggledy, one after the other, without any regard to size.

“Imagine them not round and smooth, but as angular and jaggy and scratchy as possible. Take a thousand of these strings of scratchy rocks. Lay them side by side across the country. Tie all their front ends to a gigantic harrow beam a mile long. Harness an irresistible force to this harrow beam that must drag all the strings down dale and up hill, down, down, into the sea. Pile a mountain of ice all along your band of strings of rocks, so that its tremendous weight will press the point of every rock right down through everything till it reaches the solid crust of the earth. Imagine this awful scratching machine dragged across the country for thousands and thousands of years, and you will have some idea of what a glacier can do.”

Chapter the Twentieth

Land Carving Work of Rivers



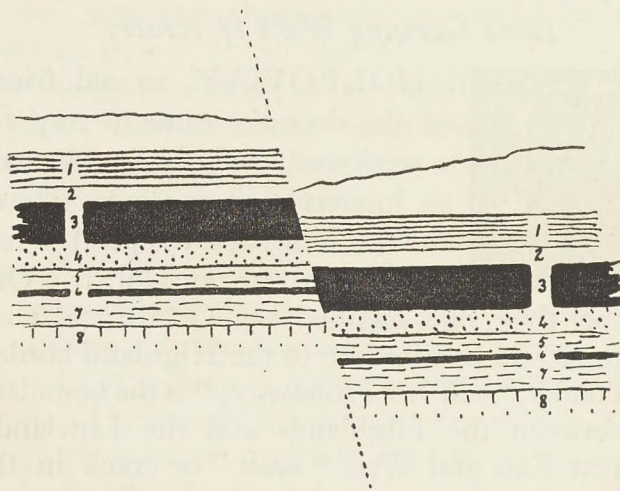
R HOLLOWAY, an old friend of the doctor's, came to stay for a week-end, and, finding Ronald so interested in geology, offered to take him back to spend a few days with him at Dollar. One morning they had climbed the Ochils, and were looking across Strathmore to the Highland border.

"Yonder," said Mr Holloway, "is the boundary line between the Highlands and the Lowlands, the great East and West "fault" or crack in the earth's crust, that runs right across the country from Helensburgh to Stonehaven. Scotland is cracked across again at the south of the Forth and Clyde valley from Girvan to Dunbar, and the slice of country between these two cracks or faults has slipped down into the earth, while at the same time the country on each side has risen.

"The Lower Old Red Sandstone formation, of which the volcanic rocks forming these Ochil Hills

Secrets of the Hills

we stand on are members, once extended over most of the country, covering up the mountains at Leadhills and the Highlands further than we now see, but they have all been washed away. The whole Midland tract of Scotland between these two great East and West faults has slipped and

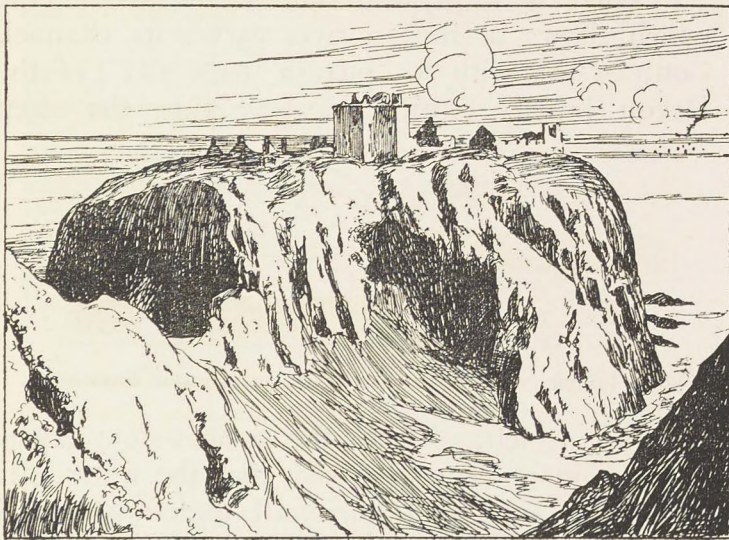


Fault.—The crust of the earth has broken through, and the rocks on the right hand side of the Fault have slipped down.

been folded down over a mile towards the centre of the earth. The coal, iron, limestone, oil shales and other useful rocks, to which Scotland owes so much of her prosperity to-day, also once extended over the greater part of the country, but they have nearly all been long since washed away except in this Forth and Clyde trough, where they have

Land Carving Work of Rivers

been preserved for us by being sunk below the level at which our rivers and burns are flowing. At the north-east corner of this trough the rocks have not only cracked right through, but have bent down in a great curve before breaking off, so that near



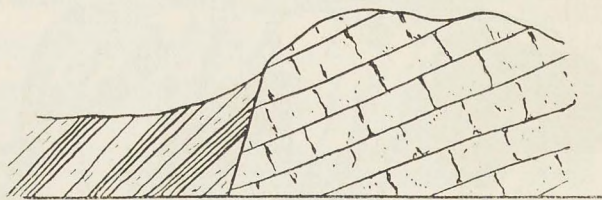
Dunottar Castle.

Stonehaven you can walk for miles across the upturned edges of rocks of Upper Silurian and Lower Old Red Sandstone age. The famous stronghold of Dunottar Castle is built on the upturned edge of one of these layers of rock. The waves of the North Sea have washed away the

Secrets of the Hills

softer layers of rock on each side of it, and by splashing up at the back of the rock on which the Castle is built, they have removed a great part of it also, until the castle now stands on a rocky island, connected to the land by a narrow ridge.

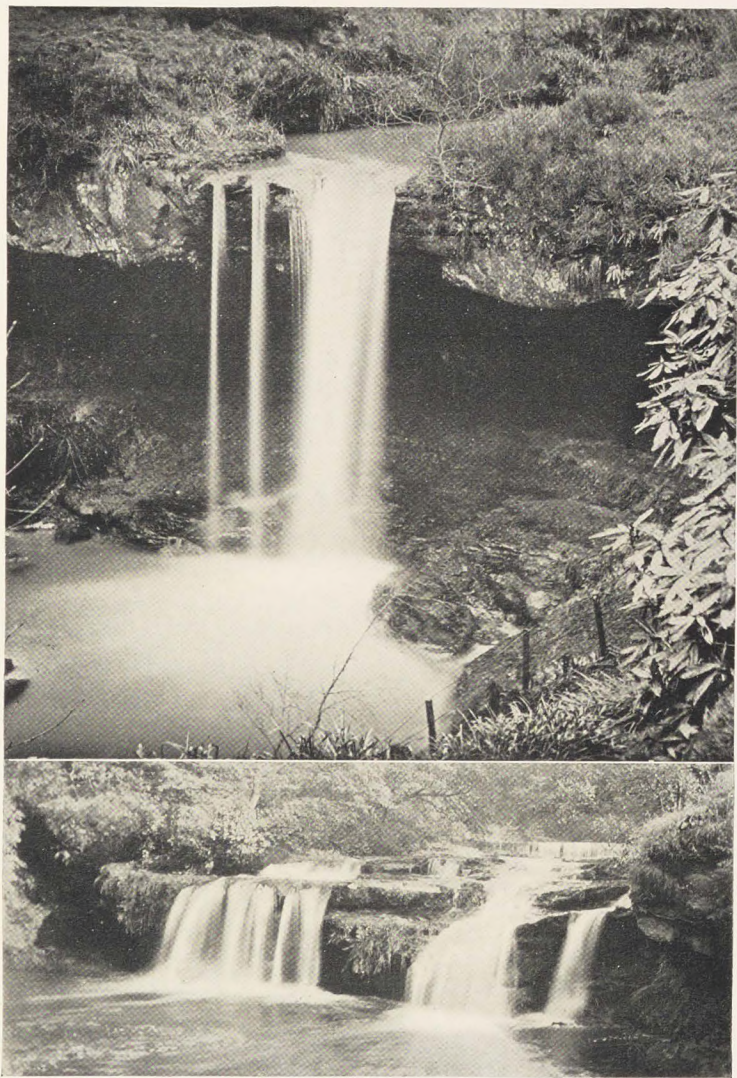
"There is a tiny waterfall in the wood here which shows us how a river carves its channel. Contrast this with the picture (page 281^A) of the Devon rapidly cutting its way into the steep



Fault, bringing different rocks next one another as at Stonehaven.

bank on its left. There, the cement-stone layers are so thin and so separated, that the water gets in at the soft layers of marl underneath, and washes them away. After the cement-stone layers are thus undermined, they quickly break off, and fall into the stream which eats into the bank inch by inch.

"Where a river has high banks, they generally supply it with plenty of boulders with which to carve its channel still deeper. This enables it to again undermine the banks at its sides and



1. Muir Mill Fall, Dollar (Photo A. Drysdale). 2. Lynn Mill Falls on Black Devon (Photo R. K. Holmes). In No. 1 note the deep pool at the foot of the Fall, and the eating away of the softer rocks and consequent undermining of the hard rock behind it. In No. 2 it will be seen that the river forms steps as it cuts its way through successive layers of rock of equal hardness.



Land Carving Work of Rivers

secure a fresh supply of carving tools from the parts of the banks that fall into it.

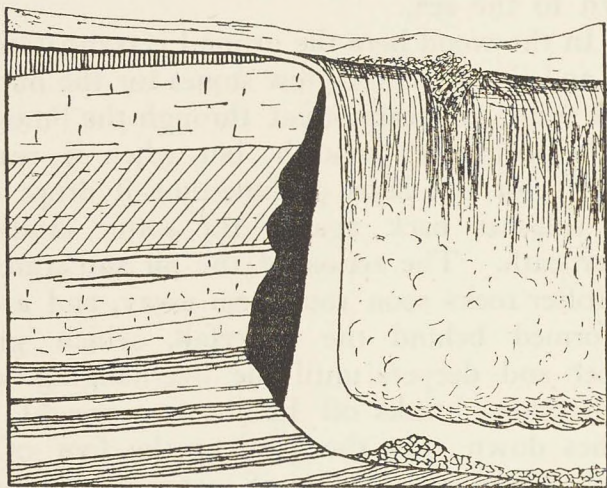
“A fast river cuts into the rock very much more quickly than a slow one, and the rate at which the river flows depends on the steepness with which the country it flows through slopes down to the sea.

“In the wood here the ground is comparatively flat, and there are very few stones for the burn to work with, so it cannot cut through the limestone to the sandstone beneath, but when it reaches the edge of the layer of limestone it drops over and splashes back against the softer sandstone underneath. The action of the air and water on the softer rocks soon rots them away, and a cave is formed behind the waterfall, which grows deeper and deeper, until the overhanging ledge of limestone breaks off by its own weight, and crashes down into the pool at the foot of the fall. There, the stream of water is continually pouring down upon the broken pieces of rock, turning them round and round on the rocks they are lying on and thus constantly boring the pool deeper and deeper. In this way the stream gradually eats its channel backward through the limestone field.

“Niagara Falls have been formed exactly in this way. The great chain of American Lakes,

Secrets of the Hills

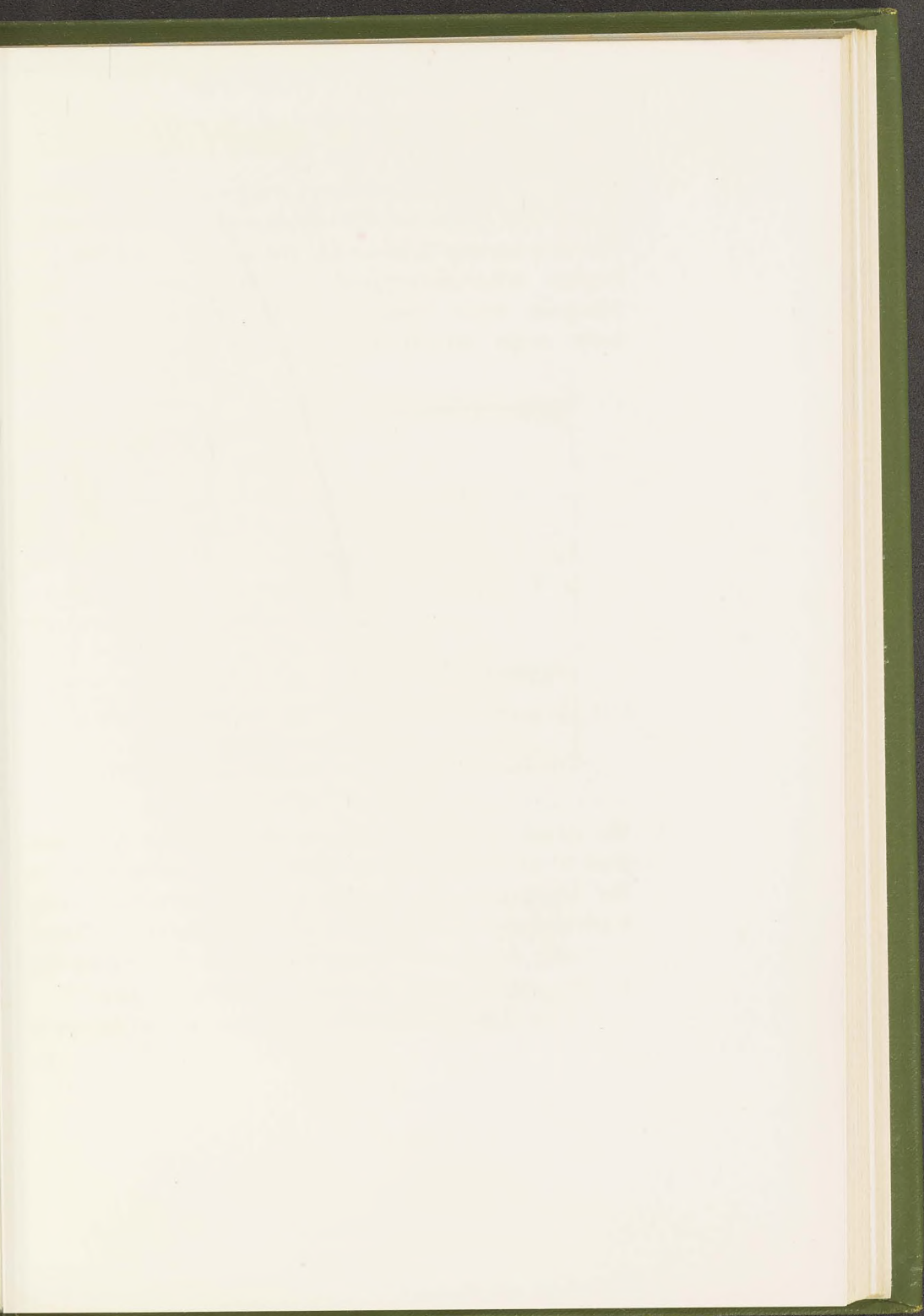
through which the St Lawrence river system flows, act as so many settling ponds, in which all the stones and sand brought down by the higher tributaries settle to the bottom. The Niagara river flows on therefore without any tools with which to scratch its way through



Section of Niagara Falls.

the sheet of hard limestone over which it moves, and it is only when it falls over the edge of the limestone that it can get at the softer rocks underneath. This edge of the limestone layer is being continually undermined and broken off at the rate of one or two feet every year.

“The Lynn Mill Falls show what happens



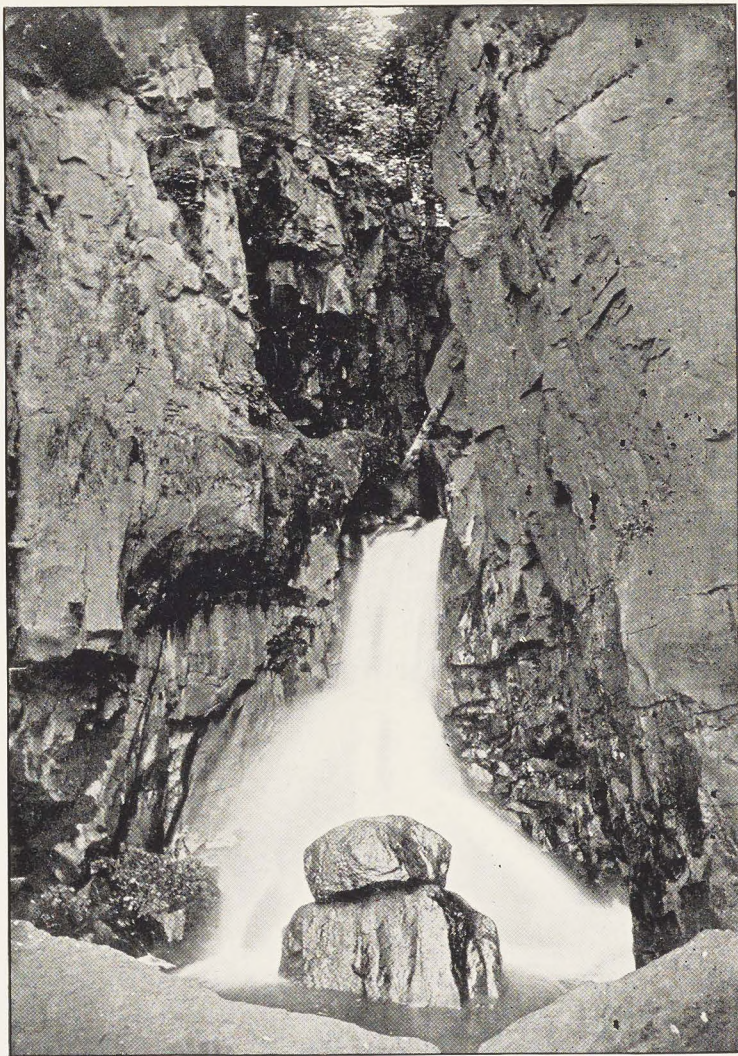


Photo by A. Drysdale

280A

Cauldron Lynn, near Dollar. This cliff of hard igneous rock is 100 feet high. The river has cut its way through by boring pot holes into its bed, and enlarging them till they broke into one another. The stream is gushing from the side of a broken pot hole, another is seen above it, and the remains of two more below to the left.



Photos by R. K. Holmes and A. Drysdale

281A

River Devon above and below Cauldron Lynn. The Devon above the lynn is a slow shallow stream, because the rock dams the river back, and it cannot cut its channel any deeper into the soft ground it is flowing over, until it has bored its way through the Cauldron Lynn rock. Note how rapidly it cuts into the marl and cement-stone layers below the lynn. The "dip" of these strata is well seen.



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when the rock barrier over which the river flows consists of several layers of equal hardness. Here the stream attacks its bed one layer at a time, always working backward, till the falls become a series of steps and stairs. The final result is a slope studded with projecting rocks and boulders, through which the water rushes, known as 'rapids.'

"We shall go this afternoon to the Cauldron Lynn, where the Devon has to tackle a bed of whinstone, one solid block, a hundred feet thick, with no layers or cracks to help the stream to cut its way through. The rock at Cauldron Lynn is the same as that of Stirling Castle, which has withstood the attacks of the great ice rivers for thousands of years.

"Every ridge of rock that crosses a stream's path acts as a barrier or dam. It doesn't matter how soft the ground behind the ridge may be, the river cannot cut its way or carve out its channel any deeper into it than the level of the top of the dam. If you put a dam across a river channel the water has to wait till it has risen high enough behind the dam to be able to flow over it.

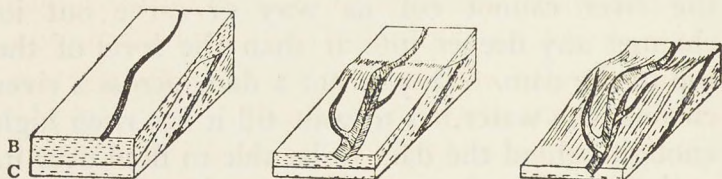
"As water always stands at the same level, a dam only three or four feet high may raise the level of the river to that height for half a mile back. As long as the water is held up it is powerless. It is only when it is running with sufficient force

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to drag stones along with it, that it can cut its way down and deepen its bed.

“As the stream rolls its stones and sand along its bed, when the stones reach the dam they must stop. The stones coming down behind them are stopped in turn, and layer after layer is deposited till the channel of the river is filled up to the level of the top of the dam.

“Once a stream succeeds in cutting the smallest channel for itself through the ridge of rock which bars its progress, it very rapidly widens it into a deep gorge. It races through this gorge and carries with it all the stones and mud it receives from its higher waters, and will soon lower the level of the whole country behind the ridge; which may be left standing as a great wall of rock stretching across a broad valley through which the river flows.



(1) River flowing over soft rocks B (2) slowly cutting into hard rock C, and then (3) carrying away soft rocks behind it.

“If it were not for these rocky barriers, which dam the rivers at various places, all the soil and

Land Carving Work of Rivers

soft ground in the country would have been washed away into the sea long ago.

"The land might be compared to a gridiron with the spaces filled in with sand. Until the iron is worn through the sand cannot be washed away.

"Before going up to the Cauldron Lynn to listen to the Devon ceaselessly boring and sawing its way through a solid block of whinstone over a hundred feet thick and half amile across; let us look at this bend where it is cutting its way into the soft bank on its left about a hundred yards below the Lynn. It is almost impossible to believe that this good-sized stream can issue through a channel only a foot broad.

"As we cannot get along by the side of the river any further, let us go through to the road, which will take us up the hill and lead us to the banks above the falls.

"The whole landscape is now so different that if it were not for the roar of the falls behind, you might refuse to believe it to be the same river, it seems so quiet, sleepy, and dreamy."

"How can the river cut its way through this intensely hard rock, and what are its tools?"

"When a blacksmith has to cut a sheet of iron, which is too thick for his ordinary tools, he drills a line of holes across it, and then saws through the intervening spaces. The Devon is boring and

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sawing its channel through this ridge in the same way. In the gorge below the falls I shall show you the remains of the line of pot holes which have had their sides broken through, and if you look into the river at our feet you can count over a dozen places where it is still boring. Some of these holes are only a few inches deep, but the others are several feet. In the winter the floods often bring with them large blocks of rock, which the river in ordinary times is unable to carry along, but which it often has strength enough to swirl round and round. If a piece of rock happens to fall on its point, or on one side which is smaller than the rest, then the force of the water will keep it moving from side to side. In this way it will grind a small hollow in the rock on which it rests. The grinding block wears itself away till it becomes small enough to be carried off by the river. An eddy is set up in the hollow and gravel is kept constantly swirling round in it. From being shallow like a saucer, the pot hole becomes as deep as a teacup.

While this boring is going on, a succession of boulders will have fallen into the hole, and if there are many stones grinding into the rock instead of one the boring goes on very much faster. The pot hole gets deeper and deeper and wider below than above. As two neighbouring pot holes

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grow deeper and wider the rock wall between them gets thinner, and in some winter flood a boulder is hurled against it and breaks through, and the two holes become one. (If you study the illustration closely you will see the remains of several of these finely polished pot holes.)

"Once the river has cut its narrow channel through the rock it has little difficulty in widening it. It whirls from side to side and undermines the cliffs. These come tumbling down and supply it with a new mass of sharp grinding tools.

"A gorge like this is always V-shaped, with

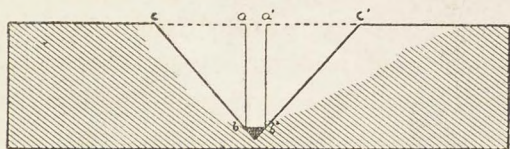
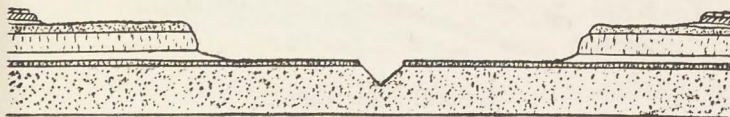


Diagram of a valley showing how it is widened by the banks continually falling into the stream.



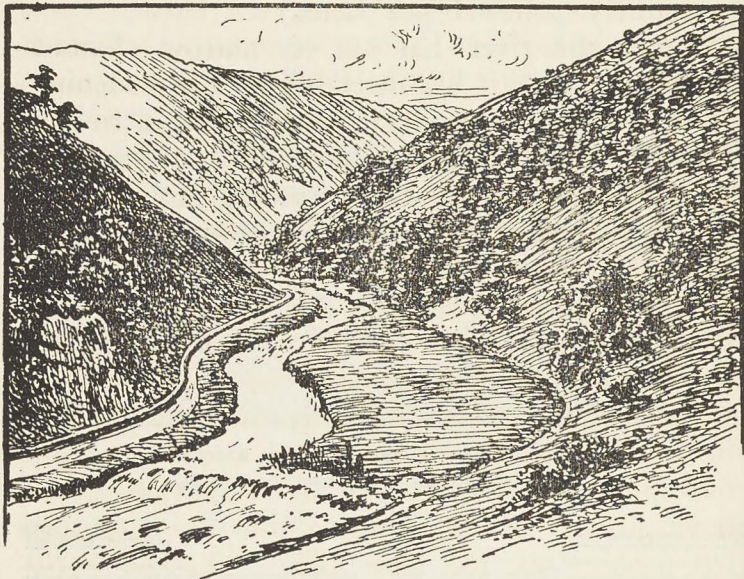
Cross section of the Colorado Canyon.

the narrowest part at the river's cutting edge, and gradually widening."

The long walk had given Ronald a splendid appetite, and after thoroughly enjoying their tea,

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he and Mr Holloway set out to walk up Glen Devon to Glen Quey, and over the water-shed into Dollar. Crossing the Rumbling Bridge they looked down into the swirling chasm, and watched



A Small River Valley.

the river tumbling and leaping, spouting and boiling a hundred feet beneath them. Ronald was fascinated, and felt as though he were gazing down at a writhing monster through a narrow chink in its prison door. His companion had

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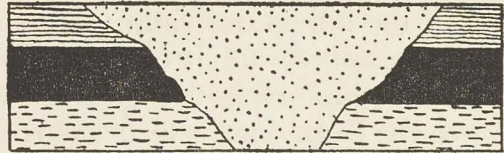
walked on, and the boy had a hard run to overtake him.

"You see, Ronald," said Mr Holloway, "as we ascend the river the valley grows narrower, and narrower, till the hills slope down into the water. At the corner here, we have a good example of the way in which a stream widens its valley. You will notice that the river originally flowed round in a great curve, and cut its way into the base of the hill on our right. It continued to undermine the hillside till it caused a landslide; all the loose earth and rocks lying on the side of the hill above the bank into which the river was cutting slipped down into the river and filled up its channel to such an extent that the stream was forced to flow over against the opposite bank, which it is now in its turn undermining. There are no trees on the side of the hill where the landslips took place, because the soil in which they should have grown has fallen down into the river, and left nothing but the bare rock. The low waterfalls and rapids (see illustration) are caused by a layer of hard rock which comes to the surface there. It dams back the river and prevents it carrying away the mass of stones and earth which have fallen into it from the hillside.

All this country-side shows proofs of glaciation. Boulder clay fills the valleys and covers the sides

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of the hill almost to their tops. We are standing on the edge of the Highland tableland. The great ice sheet crept down here, and as it melted, the water ran over the hillsides, and left the stones and boulders and sand and clay behind it. In the Ice Age, or just before it, this country stood a thousand feet higher than it does now. The old channel of the Forth has been discovered five or six hundred



Boulder Clay filling Valley of Old Forth River.

feet below the sea which now covers its valley and forms the Firth of Forth. The windings of this ancient river, buried underground for hundreds of thousands of years, are now being explored by miners digging out the coal under the sea, whose waves you watched this morning dancing in the sunshine hundreds of feet above the colliers. Without any warning, as they are working out the seam of coal, the miners strike a solid face of boulder clay and know that they have come across another bend of that old river. They drive the tunnel through the boulder clay till they come again to the seam of coal in the opposite bank,

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and then go on working it out. The buried channels of the Old Forth, and of this River Devon, which is one of its principal tributaries, have now been mapped out from information supplied by the coal workings and bores put down to locate the coal. To-day we can trace the wanderings of this prehistoric stream as it slowly carved its way down through the various beds of sandstone, and shale, and limestone, and iron and coal, which make up the carboniferous series. You might call it a fossil river composed of boulder clay. The course of the old Forth can be traced along the bottom of the North Sea towards the point where it became a tributary of the prehistoric Rhine."

As they walked up Glen Quey, Mr Holloway explained that a reservoir is formed by building a dam right across a valley, and keeping in all the water that would otherwise flow away.

"But," asked Ronald, "how do they prevent the water from running through the bottom of the reservoir. Will they cover all the bottom of the valley with clay to keep the water in?"

"No! The puddle trench, which is a wall of solid clay, will keep the water in."

"But how can the puddle trench keep the water from going through the bottom?"

"Well! Suppose some water does go through the bottom, where will it go to?"

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"Right down into the earth."

"Will it? Are there no layers of rock inside the earth, through which the water cannot go?"

"Well, I suppose there are, but what good can that do after the water has run through the bottom of the reservoir?"

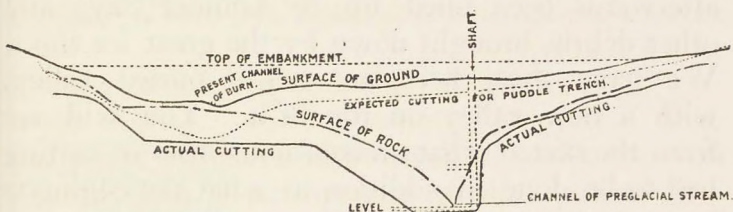
"When the water comes to a layer of rock through which it cannot flow, what does it do?"

"I suppose it has to stay above and flow slowly along the top of it, through the rocks through which it can flow."

"That is where the reservoir people catch it with their puddle trench. They cut right down through all the rocks through which the water can get, till they come to a layer of solid rock through which the water cannot flow. Then they build their dam of clay on this rock, and stretch it underground across the valley, from one hillside to the other. This wall of solid clay is continued right up to the surface. The water may sink down through the soil and all the beds of gravel and sandstone, and shales, and limestone, and through the cracks in the other rocks, but it must stop when it reaches the impervious rock. It flows along it till it meets the puddle trench, which it cannot penetrate. It fills up all the cracks in the rocks behind this wall of clay, right up to the surface. As no more water can get through the

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bottom, all the rest must stay in the reservoir. The real bottom of the reservoir is the layer of impervious rock that the puddle trench is sunk into. All the loose upper rocks might of course be removed, but as that would be very expensive they are allowed to remain, although they fill up a large part of the real reservoir. The engineer can make the reservoir as large as he wishes, by raising the puddle trench higher and higher across the



Section through Puddle Trench of Glen Quey Reservoir.

valley, so he does not trouble about the million tons of loose rocks he may have left lying in the bottom.

“ When the engineers decided to make a reservoir here, they thought that the boulder clay and the rocks beneath it, would make a perfectly solid bottom, and that they would only have to cut a shallow puddle trench across the valley. Soon after they began to cut the trench they found that the rock surface was much further down than they had calculated, and that the boulder clay, instead of being one solid mass resting on the rock,

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was in thin layers, and that there were numerous beds of gravel and running sand. After excavating a considerable length of the puddle trench from each side they were compelled to stop, and sink a shaft right down for two hundred feet, before they found really solid rock. The excavations proved that there had been an old river which had cut out this valley to a depth of two hundred feet below its present level, and that the whole valley had afterwards been filled up by boulder clay, and other débris, brought down by the great ice sheet. We have thus, here, an ancient buried valley, with a new valley on top of it. You will see from the sketch what an enormous mass of cutting had to be done in addition to what the engineers had calculated would be necessary."

Chapter the Twenty-first

The Meaning of Fossils—Evolution Theory

*For I dipt into the future far as human eye could see,
Saw the vision of the world and all the wonder that would be.*

For I doubt not through the ages one increasing purpose runs.
TENNYSON.



RONALD and the doctor were sitting out in the garden after dinner.

“I can’t understand, doctor, why geologists are always hunting for fossils even in rocks

which do not seem to contain fossils at all.”

“The reason is, Ronald, that the science of geology has been built up by the interpretation of fossils, and the theory of evolution has been established by comparing the fossil remains of extinct animals with the animals that are living to-day.

“The beginning of all knowledge is the collecting of facts. After the facts have been collected they require to be classified and arranged.

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“Many different ways of arranging plants and animals have been attempted. For centuries independent workers tried to arrange them in the orders they themselves thought best. Confusion was the result and very little progress was made. Over a hundred years ago, many scientists began to realise that some plants and animals were much more highly organised than others, and they agreed that the best way of arranging and classifying the different plants and animals, would be to begin with the simplest forms of life and gradually lead upward to the more complex organisations and higher intelligences.

“The students of Natural History arranged all their animals both with and without back-bones, and birds and fishes, in this order, and the geologists classified their fossils, and the botanists placed all the plants and trees in similar order, each arrangement commencing with the simplest form of life and leading upward to the higher.

“The next great discovery was made when the geologists began to compare their fossil animals and plants, with the living animals and plants, not for the purpose of proving that they were in all important points the same, but for the purpose of finding out how much and in what respects, the fossil forms differed from the living animals of the same kind.

The Meaning of Fossils

“This comparison showed that the fossils found in the newer rocks differed very little, if at all, from the living forms of the same animal, and that the older the rocks were in which a fossil was found, the more pronounced was the difference between it and the living animal of the same sort.

“It was next seen that the fossils found in the rocks lowest down, and therefore the oldest, were only those of the very simplest kinds of animals; while the more recent rocks contained the remains of the more highly organised animals as well as the simpler ones. If these higher animals had been living at the time the lowest rocks were formed, these rocks would certainly have contained their fossils as well as those of the lower animals. The lower rocks must, therefore, have been formed at a time before the higher animals came into existence; and the very lowest rocks, which contain no fossils at all, must have been laid down grain by grain in the far back time when the earth was without form and void, before any living thing had been created.

“Darwin came and saw all the plants and animals and fossils arranged in order, and the thought struck him, ‘this is not merely an arrangement of specimens in a museum in an order which enables anyone to know where to look

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for a particular plant or animal, but this is the order in which all plants and animals were actually created.'

"'This is not a museum collection, but a picture history of the whole world from the very beginning of time up to the present hour, and these fossils are monuments of the struggle of life to find proper expression for itself ever since the world began.'

"This idea was the foundation of the theory of Evolution."

"What is Evolution, doctor?"

"Evolution means a rolling out, an unrolling or unfolding."

"But what has that to do with our having come from monkeys? Jack told me yesterday that Evolution meant that we had all come from monkeys, and had rubbed away our tails by constantly sitting on them."

"That is quite a mistaken idea, Ronald."

"Then what does Evolution mean?"

"Do you see the big fern on the rockery there? Notice how the half-opened leaves are curled up at the top. Pluck one, unroll the curl, and you will find a perfect top to the fern, lying waiting to be unfolded. Now pluck a younger leaf still, one of those brownish stalks with a green ball at the end and a few feathery

The Meaning of Fossils

fronds sprouting from each side. Unroll the ball and you will see in it the main stem of a perfect fern leaf, and you can also undo all of the little coils on each side into which the fronds of the fern leaf are rolled up.

"Put your hand down into the root of the fern. Pick off one of the small fluffy brown balls, which are the buds of the fern leaf, and when you unroll it you will discover how the perfect leaf is evolved from the bud. The next step further back is the development or evolution of the fern plant from the seed; and in the same way we can see how the mighty oak tree was contained in the acorn, and has been evolved from it."

"Then, doctor, how did the oak tree get into the acorn?"

"Something cannot come out of nothing. Scientists are now agreed that even the lowest form of life cannot be produced by dead matter. No higher form of life could be evolved from a lower form, unless God had originally given the lower form power to rise into the higher, when its surroundings allowed it.

"Evolutionists believe that the world is still being created, that men and things are better now than they were a thousand years ago, and that they will continue to grow better and better.

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"Geologists are slowly spelling out from the fossil records in the rocks, this great story of the upward struggle of the living world towards a higher and higher life. The animal part of man's nature he shares with all the other animals in the world. He forms part of one vast living community, 'that great column of being whose base is in the sea, and on whose summit stands man.' "

"Do you mean, doctor, that all the different animals in the world are descended from the one original animal?"

"Yes, Ronald; the same life is in the flea and the elephant. They are related to each other, and both have had a common ancestor."

"Oh, doctor, surely you don't mean that; a flea is entirely different from an elephant!"

"It does seem incredible at first, Ronald, but just think for a minute of the great changes that man has brought about in the domestic animals in the short period during which he has controlled them.

"What a contrast there is between the little Shetland pony and the giant Clydesdale, and how unlike they both are to the racehorse. Yet they are all descended from the one wild horse, and their distinctive qualities are largely the result of man's interference. If he wants to produce a bigger horse than any living, he selects the two biggest horses he can find, and breeds from them, and gives

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both them and their offspring as much food as they can eat. He goes the opposite way about if he wants a smaller horse than any living. Racehorses are bred for speed, Clydesdales for strength, hunters for speed and strength, and carriage horses for beauty.

“All the different varieties of dogs, from the toy spaniel of six inches, to the great St Bernard, have been bred by men from the original wild dog or wolf. Pigeons and every other animal man has domesticated have had their characteristics changed in many different directions. If you remember how all these varieties have been artificially produced by men in a few thousand years, you can easily understand that in the course of millions of years, it is quite possible for all the existing varieties of animal life to have been produced by natural selection.”

“What do you mean by ‘Natural Selection, doctor?’”

“Darwin, Ronald, declared that all the different kinds of plants and animals have been produced by Nature from one common ancestor, in the same way that man has produced new breeds among his domestic animals. All variations from the original type are in the first place the result of accident. If the owner of the animal approves of this accidental variation, he selects it for specially

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favourable treatment, gives it plenty of food, and tries to secure that it shall attain to full development, and produce offspring having the same special qualities as itself. If he disapproves of the variation he kills it, or prevents it from having offspring. This is human selection. Nature favours certain accidental variations in the same way, but the variation has to fight for its own hand and secure its own survival. Nature selects her favourites by starvation. There is not nearly enough food in the world for all the animals that are in it. Great numbers of them, therefore, must die, and for the whole of them life is a continual struggle for food, in which the strongest conquer, and the weakest are killed, or left to die of starvation, because all the food has been eaten up by the strong ones. If by an accidental variation any animal is bigger, stronger, quicker or wiser than its fellows, it has a much better chance in the fight for food. It survives and produces offspring, and may in time establish a new breed superior to the old one.

“The conditions of life in the animal world are always changing. There may be an alteration in the climate of the country where the animals live, or in the quantity, distribution, or nature of their food, or a new race of more powerful enemies may arise to prey on them. Those who

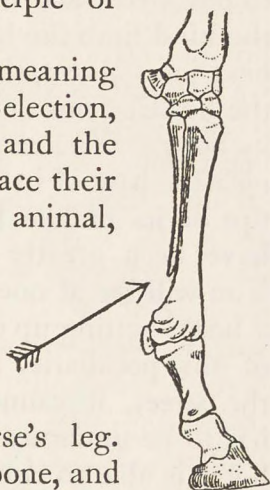
The Meaning of Fossils

are stupid enough to go on trying to live as their fathers did, die; while those who can change their way of living to suit their altered circumstances survive, and produce offspring still better fitted to live under the altered conditions of life. This is known as the principle of Adaptation to Environment.

"You will understand the meaning of these principles of Natural Selection, Adaptation to Environment, and the Survival of the Fittest if we trace their working in the case of an animal, whose family history for three million years, is now definitely known.

"I don't remember, Ronald, if I ever told you the secret of the splint bone in a horse's leg. The horse has no use for this bone, and the men who had studied it were for long puzzled to know why this bone should be there at all. The geologists discovered that this splint bone contains the secret of the horse's ancestry; and tells the story of its development from a very small animal.

"What we call the leg of a horse is really



The splint bone is embedded in the flesh of the horse's leg, and therefore cannot be seen. It can easily be felt, but choose a quiet horse.

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its hand or foot, not its arm or leg. Its hoof corresponds to your finger or toe nail; and that is why the horse is not hurt when the blacksmith drives nails into its hoof as he shoes it. What we call the knee of the horse in reality corresponds to our wrist, and the next joint to our elbow. In the hind limb the hock is really the heel, and the next joint above, the knee. The upper portions of the horse's arms or legs have been concealed within its body. You can feel its real shoulder bones up near the base of its neck. The horse walks on the tips of its middle fingers and middle toes, which have been greatly enlarged by constant exercise. You will see at once that this is true, if you watch a horse getting up or lying down; and it is because of this peculiarity that when a cart horse falls in the street, it cannot get up itself, but the cart has to be unharnessed and taken away before the horse is able to rise.

"The earliest ancestor of the horse was the 'Eo-hippus,' whose fossil remains have been traced into the oldest rocks of the Tertiary Period. It was a little animal, very like a fox terrier, but less than a foot in height, even when full grown.

"The active principle of Evolution is, that any organ of the body which is used becomes larger and stronger; and, on the other hand, any part of the body which is not used grows weaker

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and smaller, and eventually disappears altogether.

"Some fishes which live in dark caves have apparently no eyes, but when the skin covering the head is removed, rudimentary eyes are found under it. They are useless for seeing with, but



Remote ancestor of Horse that had Five Fingers and Five Toes.

they prove that the fish is descended from ancestors that had eyes and used them.




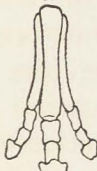
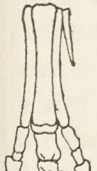
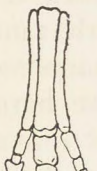
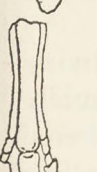
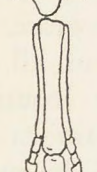


"The earliest traceable ancestor of the horse was very like a small dog. Its teeth were small, and it lived in a swampy country and fed on soft juicy plants. It had five fingers and five toes just as you have, but it began to walk principally on the middle finger or middle toe

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of each foot, and as a consequence its middle finger became longer and stronger than the others, which grew continually weaker and smaller, till in the course of two million years they have practically disappeared.

"The great - great - grandfather of the horse lived in the Eo-cene period and is therefore called the Eo-hippus. It had four large toes on its fore feet and a fifth imperfect one, but on its hind feet it had only three large toes, each with a hoof, and the middle toe-hoof was larger and longer than the others. The next stage of development was reached in an animal which has been called the Protoro-hippus or 'rising horse'; it had only four toes on its front feet, and three on its hind feet. In the fossil rocks of the Oligo-cene Period the horse is represented by the Meso-hippus. It has still three toes on its hind feet, but one of the fingers of the fore feet have disappeared, and on each leg there is now one large central toe and two small ones, which are too short to reach the ground. In the next stage, the Mio-hippus, the side toes have still hoofs, but they are gradually becoming smaller, and dying away from disuse. Finally, among the rocks which contain the fossils of man's own ancestors are found the remains of the Hipparion, which was the immediate ancestor

EVOLUTION OF THE HORSE'S FOOT

Fore Foot.	Hind Foot.	Rocks in which Fossils are found.	Name of Extinct Ancestor of Horse.	Fore Feet.	Hind Feet
		Lower Eocene.	Eo-hippus, or "beginning horse."	4 toes and splint of 1st digit. All toes touching the ground.	3 toes and splint of 5th digit.
		Upper Eocene.	Protoro-hippus = "Rising horse."	4 toes but no splint. All touching the ground.	3 toes but no splint.
		Oligocene.	Meso-hippus = "Midway horse."	3 toes and splint of 5th digit. Side toes still touching the ground.	3 toes but no splint.
		Miocene.	Hipparion.	3 toes, But side toes not touching ground, and withering away, because never exercised.	3 toes,
		Pliocene and Pleistocene.	Equus.	1 toe, And splints of 2nd and 4th digits.	1 toe,

NOTE.—These bones are not drawn to scale. The last pair are much larger than the first. As the animal which became the horse increased in size from that of a small fox-terrier 11 inches high, to our present Clydesdale, its feet would increase proportionately.

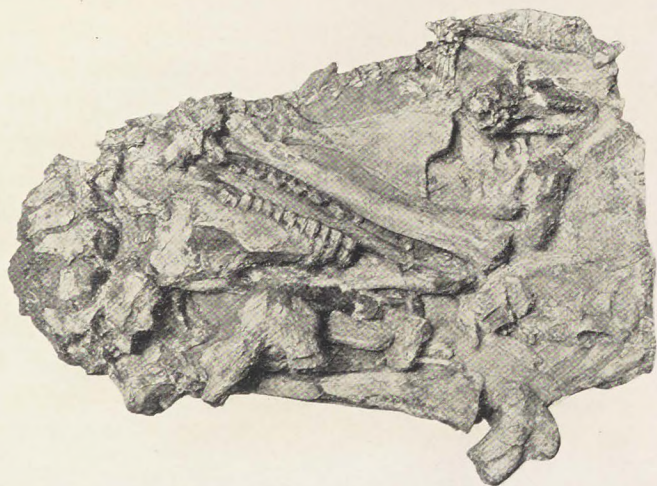
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of our horse. Now the unused hoofs have entirely disappeared, leaving only the two little splint bones to mark the place where these side hoofs belong.

"While these changes were going on in the foot of the horse in order to adapt it to the changed conditions of life, the rest of its body was altering in a similar way. As its middle finger gradually grew longer and broader until it has now become its foreleg, the horse's neck and head had to grow longer to enable it to reach down to the ground and eat the grass, and at the same time its front teeth were narrowed and sharpened so as to become better fitted for cutting the hard grass of the dry plains which it now fed on, and its back teeth became broader and more grooved and so better adapted for grinding up this grass.

"In a similar way the bodies of all living animals have been gradually but continually altering so as to enable them to live amidst altered conditions of life, in accordance with the principle of adaptation to environment.

"You, Ronald, could easily tell the difference between a horse and a bull or a donkey, and if you had studied the anatomy of those animals and knew all their bones, you could soon say to what kind of animal a particular bone belonged. If you knew all about the bones of a horse, and came



British Museum

Block of Lower Pliocene Marl, from Pikermi, near Athens, crowded with fossil bones of mammals and birds (one-twelfth natural size). The bent hind limb of Hipparion (the three-toed ancestor of our horse) is conspicuous on one side, and its skull on the other.



The Meaning of Fossils

across a fossil bone, you would be able to tell which of the horse's ancestors this bone belonged to.

"The development of life from a low to a higher form can be traced in much the same way. A geologist who has studied fossils can tell at once what kind of animal a particular bone belonged to, whether such an animal is still living to-day, or not ; and in what rocks similar animal remains will probably be found.

"No such gradual development from a lower animal to a higher can be traced in the case of man. His remains do not appear till near the close of the fossil record. He arrived very late in the day, but he arrived fully developed, and with a brain several times larger in proportion to his size than that of any other animal of the ape family. Man and monkey, like the flea and the elephant, are both descended from a common ancestor, but man has certainly not descended from a monkey.

"In body man is insignificant, in mind supreme. Have you ever seen a sheep, Ronald, hung up by the hind legs at a butcher's door, and noticed that it is taller than you are, weighs heavier, and is in many respects a superior animal ?

"The skeleton of the earliest known man differs very little from the skeletons of some primitive races living now. The brain of the man

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of the Stone Age was as big as the average brain to-day. The only advantage we have over him, lies in our machinery for education, which enables us to use the knowledge gained by our fathers, instead of having to find out everything anew for ourselves.

“ Like every other animal in Nature’s realm, man is subject to the laws of natural selection, adaptation to environment, and the survival of the fittest. But he works out his salvation with his mind rather than with his body. When changed conditions of life compel him to alter his way of living he alters his clothes or his tools instead of his skin or his bones. In a cold climate man does not adapt himself to his environment by growing a covering of thick hair like a bear, but he kills the bear and wears its skin. Instead of growing horns out of his own skull, he invents a spear, tipped at first with the horn of another animal, then with flint, and lastly with steel. The wooden club serves him as well as a lengthened arm ; the stone knife is better than any claw he could develop from his finger nails, and the arrow or the flying stone gives him the victory over animals whom he could never overcome by swiftness of foot. The thick walls of his rude hut are a better protection from his enemies than the hide of the rhinoceros or the shell of the turtle, and he stores up food for the

The Meaning of Fossils

winter instead of accumulating a store of fat in his own body, as most other animals do.

"It is this power of adapting itself to all the varying conditions of life that has made the human race immortal on the earth. Every other animal is confined to a certain part of the earth's surface and can only exist under given conditions. Man alone has spread and established himself over every part of the world at once. Owing to changes of climate and other causes great areas of the earth's surface have from time to time become incapable of supporting life, and many races of animals which were once dominant have been wiped out of existence altogether. The whole of the world has never yet been rendered uninhabitable at the same time, and therefore though millions of the human race have perished, there has always been a remnant left somewhere, which under happier circumstances has spread and repopled the earth once more.

"It is because man makes changes in his clothes or his tools instead of in his body, in order to adapt himself to altered conditions of life, that there is so little difference between the skeleton of the earliest man and the human skeleton of to-day.

"Our knowledge of the evolution of man from a lower state of civilisation to a higher has been

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gained not by studying his bones but his tools. At this point, the geologist hands over the task of writing the history of the world to the archæologist and the anthropologist. The fine workmanship of hundreds of flint implements now collected prove that man had attained to a comparatively high state of civilisation in the 'Stone Age' and his body was in many respects superior to ours."

Chapter the Twenty-Second

The Task of the Geologist

"When I see evidence for facts, they are God's facts, and they will be only my help in the end, if I can duly make use of them. The peculiarity of the Bible was that it lived through all revelations of unexpected facts."—PRIN. RAINY (*Life*, vol. ii. p. 275).



F geology is so simple, doctor," said Ronald, as he looked round the walls of the library, "why do you need all these hundreds of books about it?"

"Would it not take a hundred books, Ronald, to describe every country in the world, with all its mountains and rivers and valleys and towns; and to give the history of all its kings and peoples and buildings and roads from the beginning of time up till now?"

"Yes, it would, doctor."

"Geology, Ronald, attempts to give an account not of one world but of twenty different worlds, for every set of rocks represents a separate world, and contains a history of its inhabitants and all

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their battles, struggles, and changes, for perhaps millions of years."

"No wonder you need a lot of books, doctor."

"If all these worlds which the geologists have to describe were separate from each other, and still in existence, the work of describing them would be comparatively simple. It would only be necessary to visit each world in turn and write a careful account of whatever was found on it; but the past worlds we deal with, are buried one inside the other."

"But, doctor, if you have never cut down into the earth to find all the different worlds lying underneath one another, how do you know they ever existed?"

"Go to the drawing-room and bring that nest of Chinese baskets you were looking at yesterday."

"When I take off the lid of this violet outside basket we find an indigo-coloured basket inside it. When we open the indigo basket, we find a blue one inside; inside the blue a green; inside the green a yellow, then an orange, then a red."

"You see, now, as I place them all out on the table that it would be quite easy to describe each basket in turn. This red one might be the world in the Cambrian Age. The orange, in the Ordovician Age. The yellow, in the Silurian Age, and so on. From the fossil remains in the rocks

The Task of the Geologist

of each of these ages we could re-people each world with its living things, and judge of its climate and other conditions of life."

"But, doctor, how can the geologists separate each of the different layers of rock, and re-construct the world as it existed at the time these rocks were laid down. They cannot skin the earth like an onion, and lay all the different layers of rock out on the table like these Chinese baskets."

"I'll try to explain it to you, Ronald, if you put the seven baskets one inside the other.

"Now, when I push my finger into the side, so as to make it bulge out, and represent a mountain on the earth's surface, I press the seven different layers of straw into a little dome round my finger. If I were to shave off this dome level with the rest of the side of the basket, as the mountains are removed by denudation, I should have planed away the raised part of each of the seven baskets, and should find seven concentric circles of the different colours, each being an edge of one of the baskets I had cut through. If I press the ends of the basket together so as to make the side bulge out, and then cut away the raised pieces level with the rest of the side, I should have the cut edges of the six underneath baskets appearing,

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first indigo, then blue, green, yellow, orange, and red; then on the other side of the cut, the orange edge would come again, then next to it the yellow, green, blue, and indigo.

"Imagine that some unknown but very active force imprisoned within the nest of baskets and constantly trying to get out, had caused the surface outside to be covered with domes and puckers and folds, and that all these raised parts had been shaved off, and showed everywhere some of these seven colours, one below the other. Well, then, if I came across these different coloured edges of straw always in the same order on the outer basket, I should naturally conclude that the nest was built up of these seven different baskets, placed one inside the other.

"The earth's crust has been crumpled by constant contracting and wrinkling; the resulting raised portions have been shaved off by denudation, and thus the underlying rocks have been exposed for our inspection. But for this upheaval of great folds of the earth's crust into mountains and tablelands; and their being cut into, and carried away by the rivers, we should never have known anything of the rocks underneath us.

"The result of the earth's contraction has varied so tremendously that the brittle skin of rocks has been forced up in waves of every

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height from a few feet to twenty miles. Denudation has been so continuous and universal that the top of every one of these waves has been cut through, and every layer of rock in the earth's crust now lies uncovered on the surface somewhere. The earth's surface is made up of a patchwork of the shoulders of masses of rock that have been forced up from all the different depths and had their heads cut off. By adding together the thicknesses of the edges of all the separate layers of rock that have been thus cut through, Geologists have found that the total thickness of the sedimentary rocks in North-West Europe is over 75,000 feet.

"Here is a diagram showing the principal divisions of these rocks, which you should copy and learn by heart.

RELATIVE LENGTHS OF EPOCHS

AS REPRESENTED BY THICKNESS OF ROCKS.

TERTIARY.	1,600 ft.
CRETACEOUS.	2,500 ft.
JURASSIC.	5,000 ft.
TRIASSIC.	3,000 ft.
PERMIAN.	1,500 ft.
CARBONIFEROUS.	12,000 ft.
DEVONIAN.	4,000 ft.
SILURIAN.	7,000 ft.
ORDOVICIAN.	15,000 ft.
CAMBRIAN.	12,000 ft.
PRE-CAMBRIAN.	Extent unknown.

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"If I were to hand you a piece cut out of the side of this nest of baskets, you could easily distinguish the different layers by their colours, and tell me which of the baskets each belonged to, but the different sets of rocks which make up the earth's crust are not separately coloured for the geologist.

"You can at once see the difference between a bed of limestone and the sandstone lying above it, and the shales beneath, but you could not say to what period of the earth's history these rocks belonged, and even though you came across a seam of coal, you might be quite wrong in saying that the rocks it was found amongst belonged to the Carboniferous Period, because seams of coal are found in rocks of many different periods."

"Then how can you distinguish all the different rocks, doctor?"

"By the fossils which they contain, Ronald. Geologists laid the foundation for the Evolution theory by showing that the lowest down, and therefore oldest rocks, contained only the lowest forms of life, while each succeeding newer and higher set of rocks contained the fossils of higher and higher forms of life. After the truth of the Evolution theory had been fully demonstrated by the other sciences, geologists were able to use

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it to check their classification of the rocks, and so to be sure that if a rock contained a particular set of fossils, it must have been formed during a particular period."

"How can they prove that, doctor?"

"If a coin bearing the name of a certain king of England or emperor of Rome is found in a grave or in the foundation of a building, that coin determines the date of that grave or building, because we know that the coin could not have been put there before that king came to the throne, and was probably put there during his reign or soon afterwards. There are a large number of extinct animals whose fossil remains are as useful to geologists in determining the date of the rocks they are found in, as old coins are to the archaeologists. We know the period of the world's history during which these animals existed, and can therefore say that if a certain unknown rock contains their fossils, it must have been formed during that period.

"Geologists have now fitted all the rocks into their proper places, and determined the order of their creation, in much the same way that you can piece together the different pieces of a set of picture puzzle blocks so as to make up the complete picture. There are still a great many blanks to be filled in, and a great many theories to be

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verified, before all the worlds that have existed before this one, are scientifically reconstructed.

"Here is a chart which attempts to show some



Chart of the various stages in the Evolution of Life on the Earth.

of the stages in the history of our planet as they have been worked out by geologists.

"The conditions of life at different periods in the world's history were so varied as to constitute almost a different world. If we could skin the earth like an onion and lay aside all the different layers of rock, we could consider them as separate

The Task of the Geologist

worlds, just as we separated the nest of Chinese baskets, and laid them on the table.

“The material of which the world was made was originally shot out from the sun, and has passed through many stages of cooling, from a gaseous state to a white hot globe, when it appeared as an intensely bright star, and finally became a dead planet. Millions of years after this, it became cool enough to allow the water vapour to condense and form a sea, covering its surface.

“The earliest traces of life found in the rocks are those of sea animals. As we work our way upward through the long series of the sedimentary rocks we find the remains of the creatures which lived at the various stages in the world's history. Some of the pre-Cambrian rocks contain traces of ‘worm burrows.’ The Cambrian rocks contain the fossil shells of primitive Molluscs and a number of Trilobites. In the slaty Ordovician rocks, there are a number of markings which look as though they had been made by a lead pencil, but have been proved to be the fossil remains of primitive animals now known as Graptolites. The Silurian rocks contain a great variety of Trilobites, some of which are two feet in length, and here we also find the ancestors of the fishes which became so numerous in the succeeding ‘Old Red Sandstone’ or ‘Devonian Age.’

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“The rocks of the Carboniferous Period show a tremendous development of plant life, which forms the coal beds; and in this age the amphibious animals first make their appearance.

“During the Permian or New Red Sandstone Period the amphibians attained to great size and numbers, and some of them become distinctly reptiles. During the Triassic Age the reptiles greatly increased, and true mammals made their first appearance. The rocks of the Jurassic Period show that huge reptiles must have swarmed over the earth, and some of them had learnt to fly and were being gradually transformed into birds. The mammals are becoming more numerous and better developed. The Cretaceous or Chalk Age shows a great development in bird life. The Tertiary Period is by far the most important, for in its rocks we trace the rise of animal life to its highest development in man.

“The history of Life, the tiny speck of living jelly which appeared when the Spirit of the Lord moved on the face of the waters, and by a process of evolution extending over millions of years, developed into the human animal, with body, brain, and reason, is the most fascinating story ever written, but it requires a book for itself.”

